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ESCRIPTION OF EXPERIMENTAL FILTER PLANT AT PITTSBURGH, AND RESULTS OF EXPERIMENTS.

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DESCRIPTION OF EXPERIMENTAL FILTER PLANT AT PITTSBURGH, AND RESULTS OF EXPERIMENTS.

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[*Presented September 19, 1900.*]

GENERAL.

The city of Pittsburgh has a population of about 320 000, of which about 235 000 people are supplied with water by the municipal works, which pump from the Allegheny River. The remaining 85 000 are supplied by private companies, and almost all of the water for these people is pumped from the Monongahela River. We are interested at this time in the supply from the Allegheny. The water of this river, as regards turbidity, may be said to be midway between that of the streams of New England and of the Ohio and Mississippi valleys. It is occasionally very muddy, with large quantities of fine silt and clay. It is also polluted by sewage from many cities, towns, and mining villages, together with considerable mine drainage at times.

In June, 1896, the City Councils authorized the appointment of a Filtration Commission; to be composed of the mayor, the presidents of the councils, and eight representative citizens, two of whom were to be physicians. This commission, to quote the substance of the resolution, was to investigate the character of the present water supply, the effect of filtration, the advisability of establishing a filtration plant, and furnish an estimate of the cost of constructing and maintaining the same; also to investigate the feasibility and advisability of seeking other sources of supply.

Mr. Robert Pitcairn, general agent of the Pennsylvania Railroad, was chairman of the commission, and Mr. Allen Hazen, of New York City, was consulting engineer. Dr. Walther Riddle, of Pittsburgh, had charge of all chemical analyses, which were made in the private laboratory of Coster & Riddle. Mr. William R. Copeland,

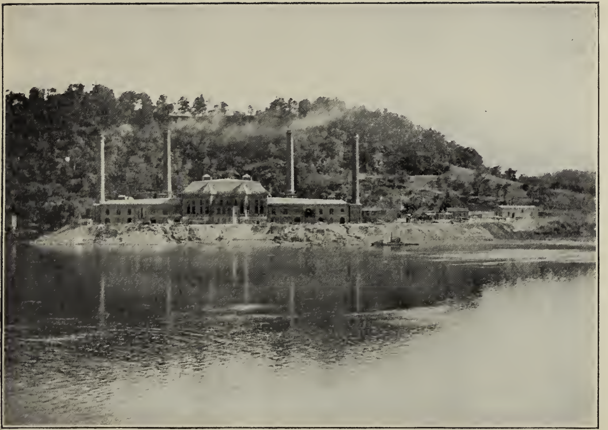

FIG. 1.—PITTSBURGH WATER WORKS. BRILLIANT PUMPING STATION AND EXPERIMENTAL FILTER PLANT.

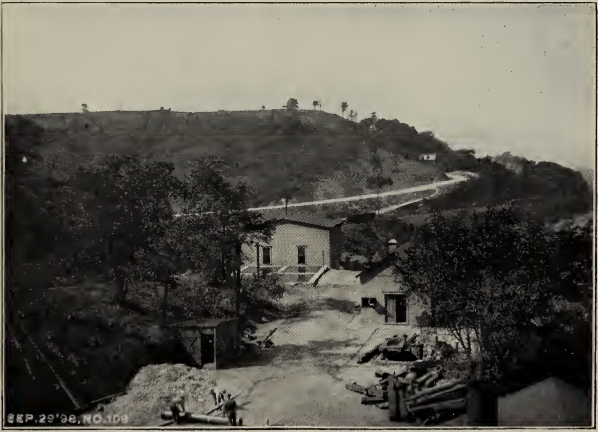

FIG. 2.—EXPERIMENTAL FILTER PLANT. SAND FILTERS AND FILTER BUILDING.

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formerly of the Experiment Station of the Massachusetts State Board of Health, at Lawrence, Mass., had charge of the bacteriological laboratory, located at the filter plant. He was also in direct charge of the operation of the experimental filters.

It is proposed in this paper to confine our attention to that portion of the investigations which was carried on at the experimental filter plant; to present a short description of the apparatus used, with views of some interesting details of the same; and to briefly summarize some of the results obtained.*

Preparations were made in May, 1897, for beginning experiments with various types of filters, and on July 23 the sand filters were placed in operation; on January 14, 1898, the mechanical filters were started. The tile filters were first started November 25, 1897, and again, after two months of idleness, on June 12, 1898. The experiments were officially closed September 1, 1898, and the report of the commission was transmitted to councils in January, 1899.

DESCRIPTION.

The experimental filter plant was located at the pumping station of the municipal water works, at Brilliant Station, on the Allegheny Valley Railway, about six miles from the City Hall. Fig. 1 shows the general arrangement, and Plate I gives some views of the plant. Plate I, Fig. 1, was taken from the north bank of the river, showing the filters and building at the extreme right. Plate I, Fig. 2, shows the settling basin and two sand filters in front of the filter building, and the elevated location of Highland Reservoir No. 1 in the background.

The plant consisted of two sand filter basins, also a settling basin of about the area of both; a filter building, in which were located the measuring vault of the sand filters, the mechanical and tile filters, the filtered water tank, the wash-water pumps and other machinery, and also the experimental boilers. Water was supplied to the plant from a large force main in the yard, and was thus of about the same character as the river water, and varied nearly as rapidly as that in the river.

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* A report upon the whole subject, together with a more complete description of the experimental work and a discussion of the results, will be found in the Report of Filtration Commission, Pittsburgh, 1899. The present paper also contains the results obtained with the experimental sand filters to January, 1900.

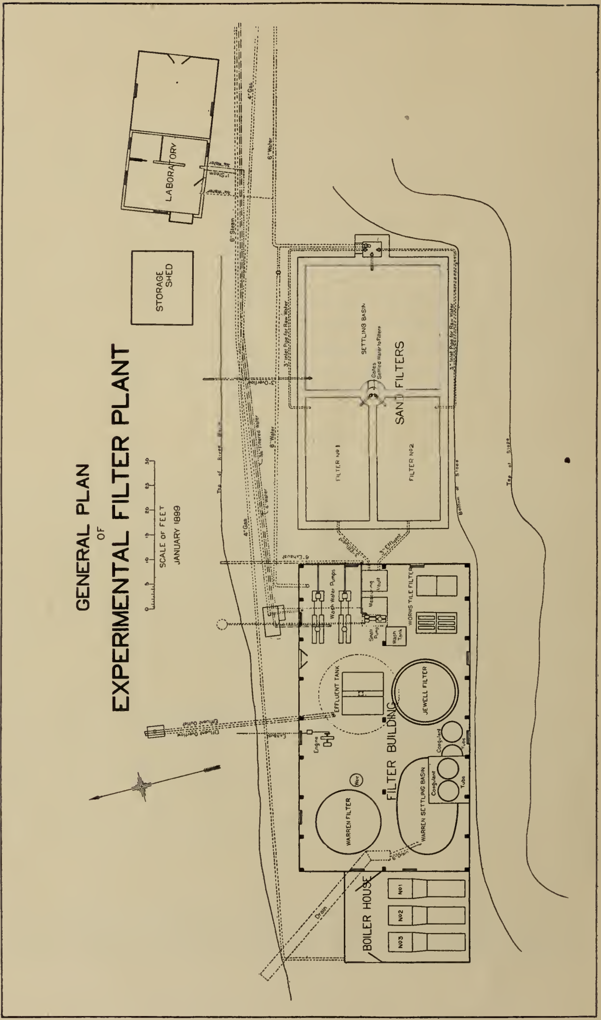
GENERAL PLAN
OF
EXPERIMENTAL FILTER PLANT
0 5 10 15 20 25 30
SCALE OF FEET
JANUARY 1899
LABORATORY
STORAGE SHED
6" Steam
4" Gas
6" Water
¾" Water
1" Steam
3" Inlet Pipe for Raw Water
SETTLING BASIN
Gates
Settled Water to Filters
SAND FILTERS
FILTER No 1
FILTER No 2
3" Overflow
¾" Filtered Water
Top of River Bank
Top of Slope
Bottom of Slope
3" Effluent
6" Exhaust
Wash Water Pumps
Measuring Vault
Small Pumps
Wash Tank
WORMS TILE FILTER
EFFLUENT TANK
JEWELL FILTER
Coagulant
Tubs
Effluent Outlet
Effluent Overflow
Exhaust
Engine
Weir
WARREN FILTER
WARREN SETTLING BASIN
FILTER BUILDING
6" Drain
BOILER HOUSE
No 1
No 2
No 3
Drain

FIG. 1.

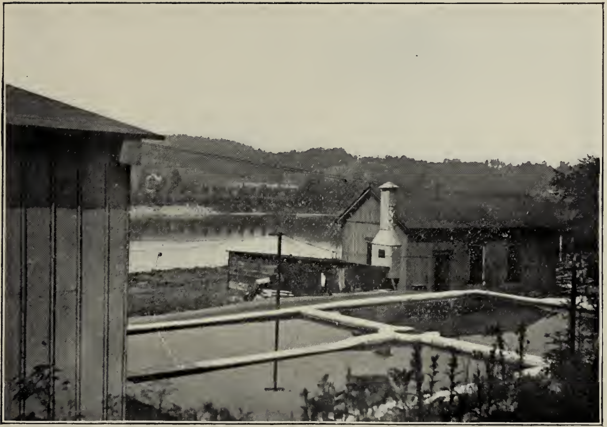

FIG. 1. — SAND FILTERS AND SETTLING BASIN.

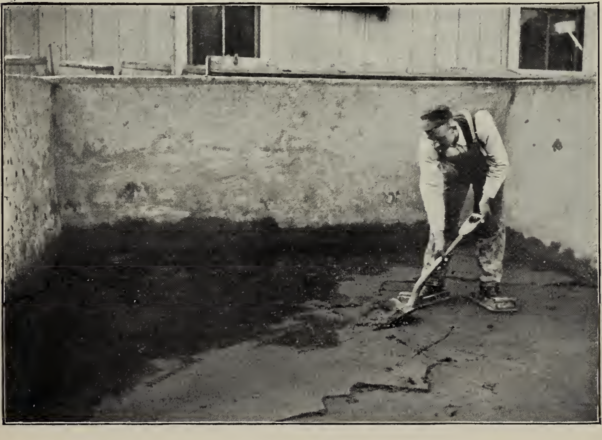

FIG. 2. — SAND FILTER. METHOD OF SCRAPING.

SAND FILTERS.

Description. A plan and vertical section of the two sand filters are shown in Fig. 2, and a view of them is given on Plate II, Fig. 1. The entire structure — that is, walls and bottom — was built of concrete, but the filters were not covered in any way. The settling basin had a capacity of about 33 800 gallons, which, if complete displacement were realized, would have allowed twenty-four hours' sedimentation when one filter only was supplied with settled water. It is believed, however, that changes from inlet to outlet were accomplished in about two thirds of this time.

The under-drains were of vitrified pipes, four inches in diameter. Broken stone and gravel, to a depth of six inches, were placed on the concrete bottom and over the pipes. The layers of under-draining material were as follows: Three inches of broken stone of about 3 inches to 2½ inches in size, which was covered with screenings or somewhat smaller broken chips, to close the larger interstices on top; 1¾ inches of clean river gravel of about ¾ inch to $\frac{5}{16}$ inch in size; 1¼ inches of clean river gravel which had been passed through a $\frac{5}{16}$-inch screen.

Allegheny River sand, which was deposited loosely in six layers for a depth of five feet, completed the beds. After it had settled in water for a few days the thickness had diminished to 4.2 feet, which was the amount in place at the beginning of the experiments. An average of 1.2 feet was removed during the thirteen months of operation. The average area of the sand surface was 0.0065 acre during the experiments, being about twelve square feet less at the close than at the beginning, owing to the batter of the walls. Plate II, Fig. 2, shows the method of scraping and the care taken by the attendant, by using sandals, not to make indentations in the sand surface. The average composition of the sand used may be seen in the following table: —

Results of Analyses of Sands used in the Sand Filters.

Source of Sample.	Effective Size. m.m.	Uniformity Coefficient.	Parts by Weight. Iron and Aluminum Oxides.	Parts by Weight. Calcium Carbonate.	Parts by Weight. Silicates and Insoluble Matter.
Filter No. 1 . .	0.30	2.0	0.98	1.32	97.70
Filter No. 2 . .	0.31	2.0	0.96	1.35	97.69

Apparatus. The effluent pipes were brought side by side into a small vault in the filter building, where the necessary devices were

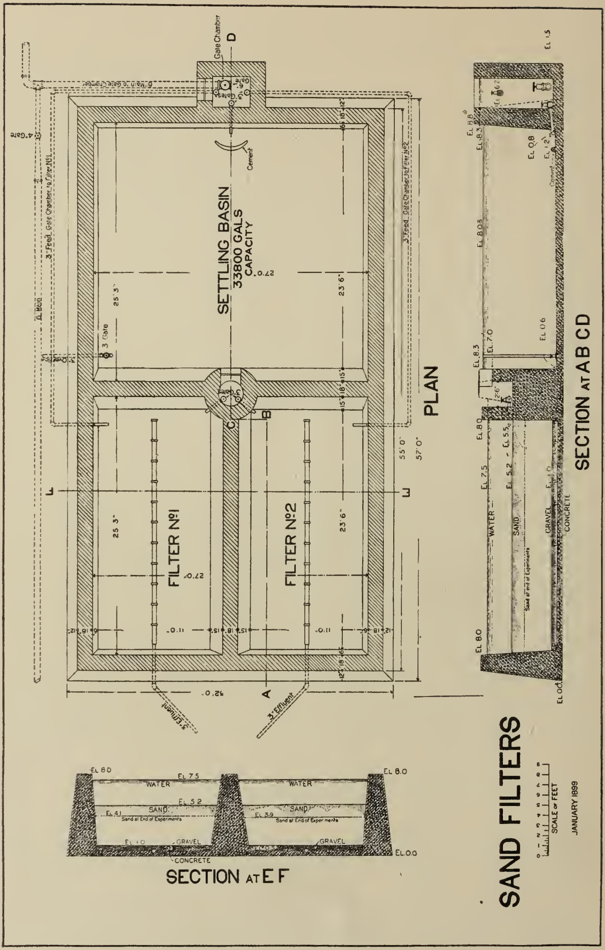
SAND FILTERS
PLAN
SETTLING BASIN
33800 GALS
CAPACITY
FILTER No1
FILTER No2
Gate Chamber
6" Main to Gate Chamber
3" Feed Gate Chamber to Filter No1
3" Feed Gate Chamber to Filter No2
4" Gate
6" Main
3" Gate
Gates
Cement
3" Effluent
3" Effluent
A
B
C
D
E
F
27' 0"
25' 3"
23' 6"
11' 0"
55' 0"
57' 0"
52' 0"
SECTION AT AB CD
WATER
SAND
GRAVEL
CONCRETE
Sand at end of Experiments
EL 8.0
EL 7.5
EL 5.2
EL 1.0
EL 0.0
EL 8.3
EL 7.0
EL 0.6
EL 0.8
EL 1.2
EL 8.8
EL 1.5
SECTION AT E F
EL 4.1
EL 3.9
Sand at End of Experiments
SCALE OF FEET
JANUARY 1899

Fig. 2.

placed for regulating and registering the rate of filtration. Meters were found unreliable on account of the amount of air in the water. Orifice indicators were therefore employed, which had the additional advantage of indicating the rate of filtration at the instant of observation. On Plate III, Fig. 1, will be seen two views of one of these indicators. Ten standard orifices were drilled in the one-eighth inch brass bottoms of copper cans, twelve inches in diameter and of the same depth. The water entered the side of the indicator and passed through a screen to prevent cross currents. On one side of the indicator there was a glass slide upon which a scale was fastened. The scale was graduated to read upon one edge in "Gallons per Orifice, Daily," and upon the other in "Million Gallons per Acre, per Orifice, Daily."

The attendant was instructed to keep the water at the half-million rate mark as nearly as possible, so that half the number of orifices open corresponded approximately to the rate of filtration. Orifices not in use were closed with rubber stoppers. The loss of head was read downward directly upon a movable scale board, the zero of which was changed frequently during the day to agree with the level of the surface of the water outside on the filter basin. Various rates of filtration were used between two million and five million gallons per acre daily, with both settled water and that which came directly from the river without any appreciable rest.

The turbidity of the river and settled waters was determined by observing the distance below the surface at which a platinum wire could be seen in the water. The record was expressed as the reciprocal of the depth, in inches, at which the wire just disappeared from view. The turbidity of the effluents was observed by comparison, in gallon bottles, with standards of known turbidity, which were made from a stock silver nitrate solution, precipitated in distilled water with sodium chloride. The relation between the two standards was determined approximately, and all results expressed in terms of the first-mentioned method.

Results. The average quantitative and bacterial results secured with the sand filters during the thirteen months are given in the following table, No. 1. The figures given in this and subsequent tables are, in some instances, slightly different from those found in the Report of the Filtration Commission. This is due to rounding up and using even figures.

Leaks and Cold Weather. In partial explanation of some of the

TABLE NO. 1.—AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

MONTHS.	Hours in Operation per Day.		Rate of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water.	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1.	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1897.														
August	23.8	22.9	2.40	2.30	0.18	0.13	—	—	2 090	1 280	46	42	97.80	97.99
September	24.0	24.0	2.98	3.00	0.05	0.04	—	—	2 480	1 230	16	16	99.35	99.35
October	23.3	23.7	2.90	2.95	0.03	0.03	—	—	72 900	39 200	32	32	99.96	99.96
November	21.5	20.1	2.64	2.42	0.26	0.18	—	—	25 200	29 900	346	632	98.63	97.49
December	22.4	23.5	2.76	2.46	0.19	0.14	—	—	14 400	14 900	163	225	98.87	98.44
1898.														
January	22.5	22.8	2.77	1.87	0.27	0.15	—	—	15 300	13 800	334	310	97.82	97.98
February	23.5	23.4	2.93	2.27	0.15	0.10	.011	.011	9 430	12 000	266	275	97.18	97.08
March	23.5	22.7	2.95	2.83	0.28	0.17	.013	.017	11 700	12 300	71	332	99.40	97.17
April	23.4	23.5	2.95	2.99	0.08	0.08	.003	.005	5 010	4 930	33	91	99.34	98.18
May	23.6	23.6	2.93	2.95	0.19	0.12	.012	.011	10 800	6 770	110	99	98.98	99.08
June	22.8	22.9	2.83	2.85	0.19	0.11	.011	.012	11 100	5 930	135	72	98.78	99.35
July	23.5	23.6	2.94	4.97	0.11	0.07	.003	.003	16 800	13 000	74	89	99.56	99.47
August	22.8	23.1	2.85	4.82	0.36	0.25	.008	.017	15 100	10 250	51	82	99.66	99.46
Average, 13 months,	23.1	23.1	2.83	2.98	0.18	0.12	—	—	16 400	12 800	128	176	99.22	98.93

NOTES.—Filter No. 1 was operated with settled water all the time, except for occasional days.

Filter No. 2 was operated with water not settled, but applied directly from the river, from July 24 to December 19, 1897, and from February 20 to June 30, 1898; and at other times with settled water.

PLATE III.

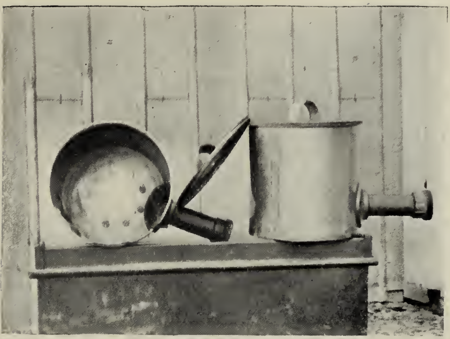

Fig. 1. — Sand Filters. Orifice Indicators.

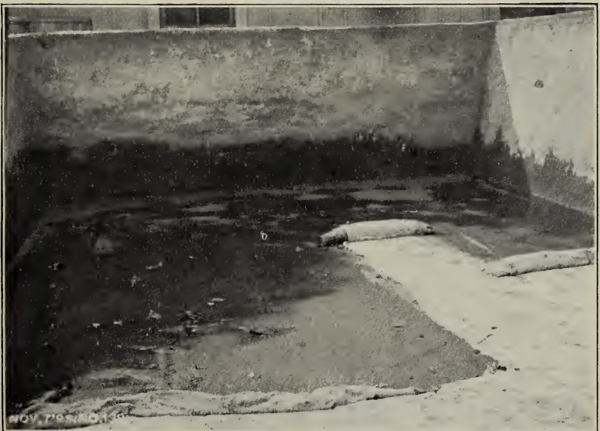

Fig. 2. — Sand Filters. Removal of Asbestos Film.

high bacterial results obtained during the cold weather, attention should be called to the cracks in the wall between the settling basin and the filters, the effect of which apparently first showed in the effluents about the middle of November, 1897. At this time it was endeavored to repair these cracks by closing them on the settling basin side, and it was then believed that this attempt was practically successful. In June, 1898, however, a small leak was again noticed ; this time a small trough was built out under the opening, so that the water was compelled to pass out into the sand, instead of down along the wall. After this no trouble was noticed. Danger from cracks of this kind is lessened by placing the filter sand on the bottom for a short distance around the walls, instead of having the gravel and broken stone up close. But much safer also is that construction which provides for a settling basin some distance from the filters, so that there is something better than a concrete wall between polluted and purified water. It is probable, however, that the lower bacterial efficiency in the winter was due in some degree to the disturbing influences of low temperature, especially upon the sand surface when exposed for scraping, upon these open and unprotected filters.

Recent Data. Through the kindness of the director of public works, Mr. E. M. Bigelow, of the superintendent of the Bureau of Water, Mr. A. B. Shepherd, and of Mr. William R. Copeland, now bacteriologist-in-charge, the writer is enabled to present, in Table No. 1A, a summary of results obtained by the Bureau of Water since September, 1898. The results for the winter months are in line with those in Table No. 1, and show markedly the influence of the cold weather.

In June, 1899, the upper foot (approximately) of the sand then remaining in the filters was removed, and new sand was placed in them to a depth of three feet; then about nine inches of the old material was replaced, bringing the sand surface about to the original grade. For this reason the average results for the first six days of June, 1899, are reported separately from those for the last nineteen days. However, the average for the year 1899 was obtained by using an average for June, giving the proper weight to the duration in time of each group of results.

Five baffle walls were used after August 23, 1899, in one half of the settling basin, which caused the water applied to Filter No. 2 to travel in a tortuous course, horizontally, and thus gave a more complete displacement.

TABLE NO. 1A. — AVERAGE OF DAILY RESULTS WITH SAND FILTERS, BY MONTHS.

(AFTER AUGUST, 1898.)

MONTHS.	Hours in Operation per Day.		Rate of Filtration, Million Gallons per Acre Daily.		Turbidity.				Bacteria per Cubic Centimeter.				Percentage of Bacteria Removed.	
					Raw Water.	Settled Water.	Effluents.		Raw Water.	Settled Water.	Effluents.			
	No. 1	No. 2.	No. 1.	No. 2.			No. 1.	No. 2.			No. 1.	No. 2.	No. 1.	No. 2.
1898.														
September . . .	23.4	22.1	3.04	4.67	0.04	0.03	.004	.006	18 100	17 500	54	120	99.70	99.34
October	23.8	21.9	2.90	4.62	0.11	0.09	.003	.003	35 200	34 600	100	140	99.72	99.60
November . . .	23.7	20.7	3.09	2.61	0.10	0.10	.010	.009	15 700	12 000	190	325	98.79	97.93
December . . .	22.0	22.7	2.85	2.73	0.11	0.08	.005	.006	22 400	19 400	940	850	95.80	96.21
Average, 1898 . .	23.2	22.7	2.92	3.35	0.17	0.11	.008	.009	15 700	13 600	197	233	98.75	98.58
1899.														
January	24.0	23.3	3.06	3.01	0.15	0.13	.016	.012	29 700	38 300	506	360	98.30	98.79
February . . .	22.4	23.4	2.97	3.10	0.15	0.10	.008	.007	12 600	16 200	380	340	96.99	97.31
March	23.3	23.4	3.15	2.95	0.21	0.18	.021	.021	17 400	16 800	179	282	98.97	98.38
April	23.3	23.3	3.17	3.08	0.10	0.09	.016	.012	7 000	7 110	65	64	99.07	99.09
May	22.4	23.5	2.99	3.12	0.14	0.13	.008	.012	10 000	9 810	114	128	98.86	98.72
June, 6 days . .	23.2	24.0	3.07	3.12	0.18	0.09	.012	.010	5 730	3 840	79	106	98.62	98.15
June, 19 days . .	24.0	23.9	2.02	2.00	0.16	0.13	.016	.016	13 600	4 900	1 500	1 010	89.00	92.60
July	22.2	22.8	2.40	2.44	0.20	0.18	.011	.015	8 250	4 640	218	128	97.36	98.45
August	23.2	23.4	2.92	2.89	0.27	* 0.24 0.17	.015	.016	20 400	* 14 900 18 700	56	86	99.73	99.58
September . . .	23.2	23.2	2.93	2.94	0.16	* 0.15 0.13	.010	.009	23 600	* 15 800 16 100	56	44	99.76	99.81
October	23.2	23.3	2.97	2.97	0.04	* 0.04 0.04	.002	.002	41 500	* 29 900 26 500	48	45	99.88	99.89
November . . .	21.7	21.7	2.68	2.64	0.15	* 0.14 0.13	.006	.005	13 500	* 10 900 16 200	405	79	97.00	99.41
December . . .	23.0	22.6	2.64	2.79	0.18	* 0.17 0.14	.012	.013	15 000	* 13 300 12 400	121	165	99.19	98.90
Average, 1899 . .	23.0	23.1	2.85	2.84	0.16	0.13	.012	.012	17 600	15 400	272	207	98.45	98.82
January, 1900 . .	21.7	21.1	2.44	2.34	0.19	* 0.14 0.13	.012	.014	22 100	* 27 800 21 400	463	535	97.90	97.58

NOTES. — Settled water was applied to both filters all the time, except for occasional days.
Averages of both periods in June, and, for records starred, the average of both results, were used in computing yearly averages.
* First result given where starred refers to water applied to Filter No. 1, and second result to that applied to Filter No. 2.

Asbestos pulp was used on the surface of Filter No. 2 in different quantities, from October 27 to November 12, 1898. From November 2 to December 13, 1898, sulphate of alumina was added to the applied water, as it entered the settling basin, at rates varying from one quarter of a grain to one grain per gallon. Neither of these special experiments was productive of conclusive evidence, as the time of trial was limited, and the facts are recorded here solely in order that the full history to accompany Table No. 1A may be given. Plate III, Fig. 2, shows how the asbestos pulp may be rolled up like a carpet when dried to the proper degree.

Periods between Scrapings. The following tables, No. 2 and No. 2A, contain the results of the runs between scrapings, the first until September, 1898, and the second from that time to January, 1900. The results for Filter No. 1, in Table No. 2, differ slightly from the summaries given in the Report of the Filtration Commission, as the data has been entirely recalculated from the original records, to give the result at the exact time that the loss of head reached four feet.

Not all the periods have been included in Table No. 2A. When special tests with asbestos were conducted and when, for experimental purposes, very small depths of sand were removed at a scraping, which created for the next run a large initial loss of head, greater than one foot, some of the results are omitted from the tables.

In Tables No. 2 and No. 2A, it will be noticed that there appears to be some relation between the length of period, or quantity filtered between scrapings, and the average turbidity for the period. In general, the more turbid the water, the less the length of the period and the less the quantity filtered, but the relation is not an exact one. On the diagram, Fig. 3, the results in Tables No. 2 and No. 2A have been plotted, using the quantity filtered as ordinates, and as abscissæ the square of the average turbidity during the period divided by the average rate of filtration. It will be seen that many points are some distance away from the average line, yet there does seem to be some general relation.

It may be that the storage of suspended matter in the sand, as evidenced by the turbidity of the effluent long after the muddy water has passed by, affects the length of the period to some degree. The length of the period is also undoubtedly influenced somewhat by the variation in the temperature of the applied water; the low temperature in winter causing a greater loss of head than in the warmer

TABLE NO. 2.—QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

Number of Period.		Number of Days.		Average Turbidity.				Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet Removed at Scraping.	
				Applied Water.		Effluent.					
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
1	2	22.8	14.7	0.13	0.27	—	—	44.6	30.8	0.04	0.04
2	3	45.7	37.1	0.06	0.06	—	—	135.9	111.3	0.06	0.04
3	4	32.9	37.0	0.03	0.04	—	—	98.8	111.8	0.05	0.06
4	5	17.9	4.2	0.20	0.54	—	—	53.1	12.1	0.05	0.07
—	6	—	11.0	—	0.24	—	—	—	32.7	—	0.09
5	7	18.2	21.4	0.15	0.16	—	—	54.1	51.0	0.13	0.05
6	8	12.1	17.0	0.07	0.18	—	—	36.0	34.1	0.03	0.04
7	9	12.1	9.4	0.21	0.14	—	0.022	35.9	18.6	0.05	0.10
8	10	11.2	29.1	0.10	0.10	0.012	0.011	33.1	69.1	0.10	0.06
9	11	30.5	18.6	0.10	0.13	0.012	0.009	91.3	56.8	0.07	0.06
10	12	26.4	4.2	0.21	0.98	0.014	0.046	79.8	12.3	0.12	0.13
—	13	—	14.4	—	0.14	—	0.013	—	43.8	—	0.07
11	14	32.8	26.4	0.06	0.08	0.002	0.002	99.2	81.1	0.07	0.07
12	15	33.3	23.8	0.10	0.21	0.014	0.015	100.2	72.1	0.07	0.10
—	16	—	16.1	—	0.22	—	0.008	—	48.4	—	0.11
13	17	30.0	17.2	0.12	0.15	0.007	0.013	90.4	69.3	0.09	0.06
14	18	30.8	22.5	0.21	0.07	0.003	0.001	92.8	114.4	0.13	0.07
—	19	—	17.7	—	0.28	—	0.012	—	89.5	—	0.12
Average		25.5	19.0	0.12	0.15			74.7	58.8	0.08	0.07

TABLE NO. 2A.—QUANTITATIVE RESULTS OBTAINED DURING EACH PERIOD OF OPERATION WITH THE SAND FILTERS, THE LOSS OF HEAD BEING LIMITED TO FOUR FEET.

(AFTER AUGUST, 1898.)

Number of Period.		Number of Days.		Average Turbidity.				Quantity Filtered, Million Gallons per Acre.		Depth of Sand in Feet Removed at Scraping.	
				Applied Water.		Effluent.					
No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
16	20	29.8	22.3	0.05	0.09	0.006	0.018	72.3	112.3	0.05	0.09
17	21	30.6	33.8	0.06	0.03	0.001	0.002	71.7	179.1	0.09	0.09
18	—	19.8	——	0.10	——	0.014	——	64.0	——	0.07	——
19	27	10.2	13.4	0.05	0.04	0.004	0.000	33.9	41.6	0.10	0.24
20	28	16.2	13.4	0.04	0.09	0.000	0.002	51.2	41.2	0.09	0.09
21	—	9.9	——	0.20	——	0.016	——	30.7	——	0.15	——
22	29	34.1	28.1	0.12	0.14	0.013	0.014	100.6	86.6	0.11	0.17
23	30	12.3	27.3	0.05	0.06	0.005	0.006	39.4	84.1	0.09	0.08
24	31	30.1	30.2	0.20	0.21	0.022	0.019	96.3	94.0	0.24	0.12
25	32	31.3	36.1	0.11	0.12	0.020	0.016	98.5	109.7	0.09	0.06
26	33	23.2	38.2	0.04	0.10	0.005	0.011	76.3	121.8	0.04	0.06
27	—	15.0	——	0.11	——	0.011	——	18.4	——	0.04	——
28	34	19.4	19.1	0.16	0.16	0.012	0.015	38.3	37.8	0.05	0.06
29	35	17.0	18.0	0.14	0.17	0.012	0.016	48.0	48.9	0.19	0.08
30	36	23.0	23.0	0.21	0.23	0.016	0.019	70.1	73.7	0.06	0.08
31	37	23.0	28.0	0.22	0.12	0.012	0.010	69.7	82.6	0.11	0.10
32	38	38.0	36.5	0.06	0.05	0.004	0.003	118.2	107.4	0.06	0.04
33	39	10.0	6.0	0.12	0.13	0.002	0.001	29.4	20.9	0.03	0.02
34	40	9.6	10.0	0.09	0.09	0.007	0.004	31.0	30.6	0.05	0.05
35	41	9.0	11.0	0.13	0.12	0.007	0.007	26.4	32.5	0.04	0.05
36	42	8.2	10.5	0.06	0.06	0.008	0.008	23.0	26.4	0.03	0.04
37	43	5.2	3.5	0.25	0.33	0.007	0.017	14.3	9.5	0.08	0.04
Average		22.5	26.3	0.11	0.11	0.010	0.010	64.6	87.2	0.10	0.10

NOTES.—During periods 22-26, inclusive, for filter No. 2, asbestos was used on the surface.
For the last five periods of each filter, small depths of sand were removed at scrapings, which caused an initial loss of head greater than one foot, and decreased the lengths of the periods. The results of these periods were not used in computing the averages.

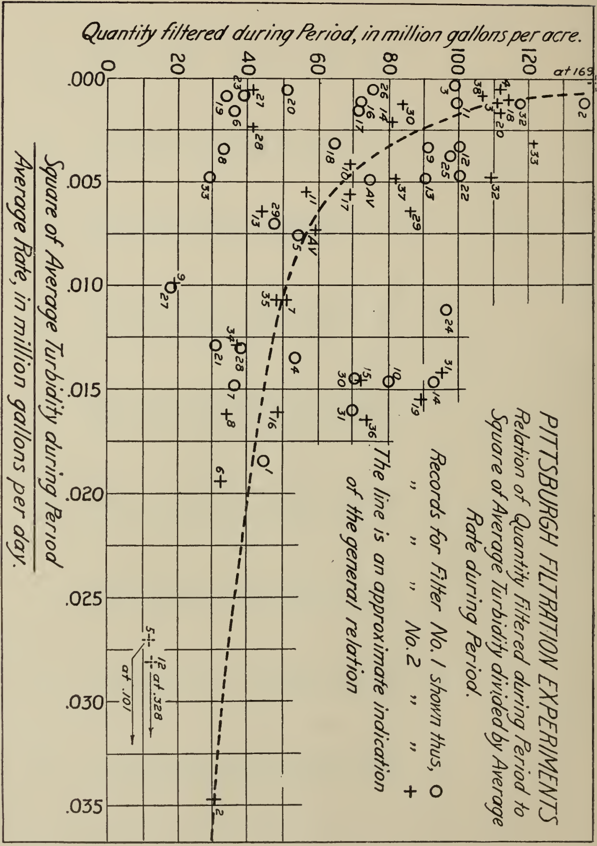
PITTSBURGH FILTRATION EXPERIMENTS
Relation of Quantity Filtered during Period to Square of Average Turbidity divided by Average Rate during Period.
Records for Filter No. 1 shown thus, O
" " " No. 2 " " +
The line is an approximate indication of the general relation
Quantity filtered during Period, in million gallons per acre.
0
20
40
60
80
100
120
at 169
Square of Average Turbidity during Period / Average Rate, in million gallons per day.
.000
.005
.010
.015
.020
.025
.030
.035
12 at .328
5 at .101

FIG. 3.

weather, to filter the same quantity. It is probable, however, that these factors are obscured by the errors in determining the effect of the water upon the filters, in regard to depositing a clogging layer, but, more than anything else, the diagram teaches us that a more accurate method of observing turbidity is needed.

The question of this relation is an interesting and even an important one, for if, by continuous and systematic observations of the turbidity of a source of supply, the probable quantity of water that will be filtered between scrapings can be determined, the largest item of the cost of maintenance of slow sand filters may be accurately estimated without waiting for the actual trial of filters.

TABLE NO. 3.—AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER AND SAND FILTERS DURING THE THIRTEEN MONTHS ENDING AUGUST 31, 1898.

(Parts per 100 000.)

CONSTITUENTS.	River Water.	Outlet from Settling Basin.	Effluents.		Percentage of Constituents Removed.	
			No. 1.	No. 2.	No. 1.	No. 2.
Color	0.29	0.27	0.09	0.09	69	69
Nitrogen as						
Albuminoid Ammonia	0.0116	0.0108	0.0063	0.0064	46	45
Free Ammonia	0.0019	0.0019	0.0016	0.0016	16	16
Nitrites	0.0000	0.0000	0.0000	0.0000	. .	. .
Nitrates	0.0684	0.0641	0.0715	0.0647	- 5	5
Chlorine	2.19	2.08	2.06	2.02	6	8
Total Solids	15.9	13.1	12.1	12.1	24	24
Suspended Matter	4.2	1.3	0.0	0.0	100	100
Total Hardness	3.58	3.69	4.72	4.83	- 32	- 35
Alkalinity	2.89	3.07	4.13	4.22	- 43	- 46
Sulphuric Acid	1.44	1.38	1.44	1.44	. .	. .
Iron	0.052	0.060	0.016	0.018	69	65

Chemical Results. Table No. 3 gives the average results, for the whole period of the test, of the chemical analyses of samples of water collected from the Allegheny River, from the outlet of the settling basin, and of the sand filter effluents, together with the percentage of chemical constituents removed. Tables 12A to 12E, at the end of this paper, contain the monthly averages of the results of the chemical analyses and average summaries for different periods.

WARREN FILTER.

This filter was located in the westerly portion of the filter building. Fig. 4 shows a plan and Fig. 5 an elevation. The system consisted of a settling basin, having baffle walls, and a circular tank, or filter proper, which contained the filter sand, agitating, washing, and regulating devices.

Settling Basin. The capacity of the settling basin was about 11 200 gallons, which gave, if complete displacement were accomplished, a period of about fifty minutes for the water to pass from one end to the other, when the filter was operated at a rate of 120 million gallons per acre daily. Just before the water entered the settling basin it was measured by a meter and then at the entrance was controlled by a butterfly valve, which was attached to a float in the basin. Next, the water passed through a propeller which operated the revolving coagulant pump, or tympanum, on the platform above.

Coagulant. The solution of coagulant was introduced as the water passed the propeller. The average composition of the sulphate of alumina, which was the coagulant used in both Warren and Jewell filters, was:—

	Parts by Weight.
Alumina oxide, soluble in water	17.18
Iron oxide	0.00
Suplhuric acid	38.66
Material insoluble in water	0.24

The coagulant solution was dissolved in two tubs placed on top of the settling basin, and allowed to flow first from one, then from the other, into the tank in which the tympanum was placed. The inner end of each arm of this pump was connected to one of a series of six tubes placed in the hub and parallel to the shaft. As the pump revolved, each arm in turn was filled; as the arm became elevated, the solution passed down into the hub, out into a lead cup on the side of the tank, and thence to the settling basin below. A view of the coagulant tubs with tank and tympanum is shown on Plate IV, Fig. 1, and the exit of pipe in the settling basin in Fig. 2 on the same plate.

The level of the solution in the pump tank was kept as constant as possible by rubber float valves. It was found, however, that

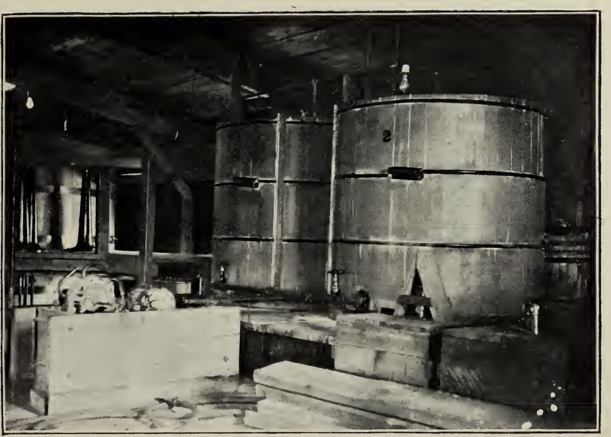

Fig. 1.—Warren Filter. Coagulant Tubs and Chemical Pump.

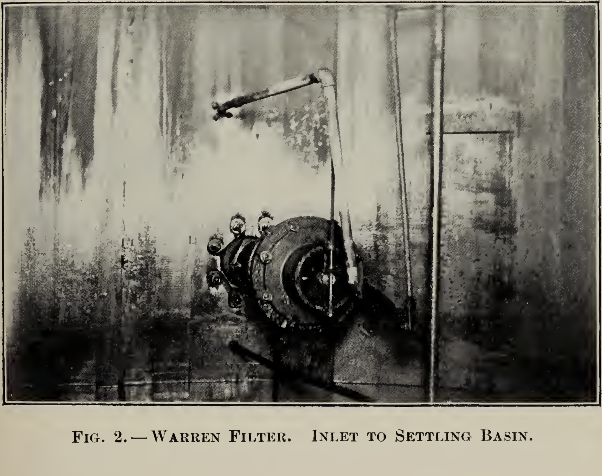

Fig. 2.—Warren Filter. Inlet to Settling Basin.

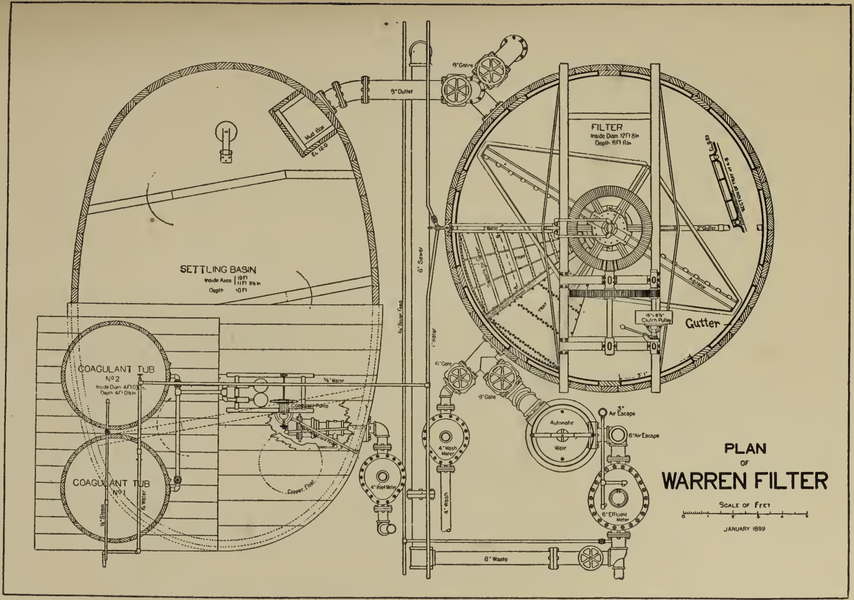
PLAN
OF
WARREN FILTER
SCALE OF FEET
0 1 2 3 4 5
JANUARY 1899
FILTER
Inside Diam 12 Ft 8 In
Depth 8 Ft 6 In
SETTLING BASIN
Inside Axes 19 Ft | 11 Ft 9¾ In
Depth 10 Ft
COAGULANT TUB No 2
Inside Diam 4 Ft 0¾ In.
Depth 4 Ft 0½ In
COAGULANT TUB No 1
Mud Box
EL. 12.0
8" Outlet
8" Gate
8" Sewer
¾" Boiler Feed
1" Water
¾" Water
½" Steam
Coagulant Pump
Copper Float
4" Inlet Meter
6" Gate
8" Gate
4" Wash Meter
4" Wash
Automatic Weir
3" Air Escape
6" Air Escape
6" Effluent Meter
6" Waste
2" Gutter
Gutter
Agitator
Tray
Supports for Strainer
18" × 6½" Clutch Pulley
Section of Tray at A-B
EL. 8.83

FIG. 4.

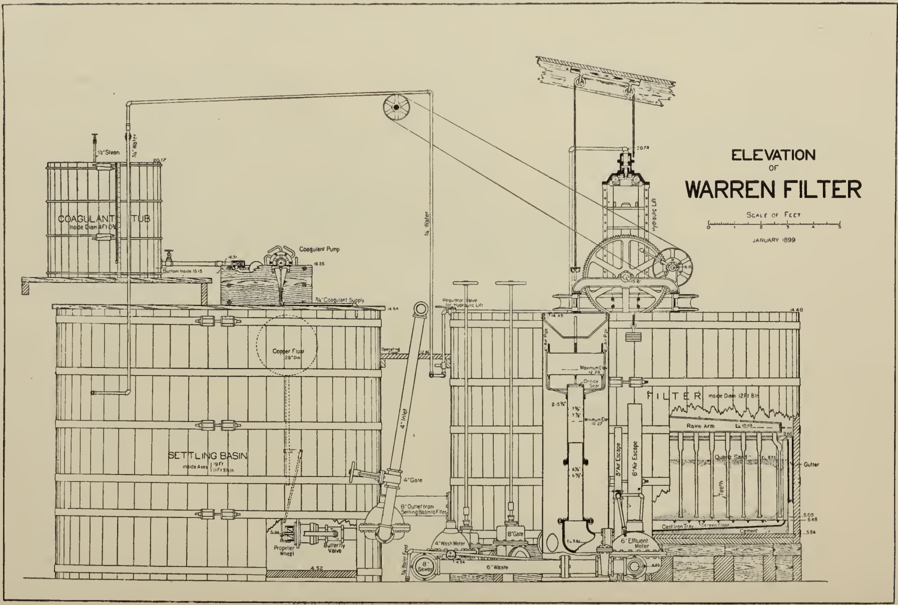
ELEVATION
OF
WARREN FILTER
SCALE OF FEET
0 1 2 3 4 5
JANUARY 1899
½" Steam
¾" Water
20.1F
COAGULANT TUB
Inside Diam 4 Ft 0¾
Bottom Inside 15.13
16.31
Coagulant Pump
18.25
¾" Coagulant Supply
18.54
¾ Water
Copper Float 28" Dia.
Operating Floor
12.86
SETTLING BASIN
Inside Axes 19 Ft 11 Ft 9½ In
4" Inlet
4" Gate
8" Outlet from Settling Basin to Filter
Propeller Wheel
Butterfly Valve
4.52
¾ Boiler Feed
8" Sewer
4.34
4" Wash Meter
6" Waste
8" Gate
Regulator Valve for Hydraulic Lift
Hydraulic Lift
20.78
15.8
16.16
14.45
Air Pipe
Maximum Elev 12.28
Orifice Seal
2-5¾"
7⅜"
7⅞"
Minimum Elev 10.27
6⅜"
6⅞"
El. 5.61
8" Air Escape
6" Air Escape
6" Effluent Meter
4.86
FILTER Inside Diam 12 Ft 8 In
14.46
Rake Arm
El. 10.03
9.65
Quartz Sand
El. 8.73
Teeth
Gutter
Cast Iron Tray
Screen Floor
Cement
6.60
6.46
5.94

FIG. 5.

this method was not entirely satisfactory, as the valves frequently became clogged. Also, when a new solution was first used, the higher elevation of the liquid in the pump tank, due to the pressure from a full tub above, caused much more coagulant to be added to the applied water than when the solution in the upper tub had nearly run out. It was endeavored to remedy this by opening the valve from the coagulant storage tub a little only at the beginning and gradually increasing this opening as the tub became empty. Even with this care the rate of application of the coagulant solution was not constant.

TABLE NO. 4.—VARIATIONS IN THE APPLICATIONS OF COAGULANT TO MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Amount of Sulphate of Alumina Used, in Grains per Gallon.			Percentage of Variation from the Average.	
			For Duration of Thirty Minutes.		Average for Duration of Experiment.		
			Highest.	Lowest.		Highest.	Lowest
1	April 14	Warren	0.91	0.39	0.55	+ 66	- 29
2	„ 14	Jewell	0.53	0.26	0.34	+ 56	- 24
3	June 10	Warren	2.48	0.80	1.30	+ 91	- 38
4	„ 23	„	3.96	0.66	2.19	+ 81	- 70
5	„ 23	Jewell	2.48	1.05	1.90	+ 31	- 45
6	August 12	Warren	3.86	0.91	1.57	+ 146	- 42
7	„ 12	Jewell	2.09	0.65	1.11	+ 88	- 41
Averages,			2.33	0.67	1.28	+ 82	- 48

Without quoting in detail the tables which are published in the report, the brief summary in Table No. 4 will show the nature and amount of this variation, both for the Warren and Jewell filters. It must be remembered, however, in studying this table, that it is more difficult to apply small quantities of a coagulating liquid in an accurate manner than it is to do similar work on a large scale.

Filter. The filter proper was composed of a circular tank with a sand area of 118 square feet. On the bottom, inside, there were placed radial iron troughs, set in concrete, which served as a support for a brass strainer floor, and also as collectors for the filtered water. From the bottom of the tank and connected directly with the inlet pipe, there was a central well which extended up through the filter floor, and above the sand surface. Attached to this well and between the collecting troughs, there were ten two-inch horizontal pipes, which were connected with vertical iron gutters, placed around the filter inside the staves.

The inlet water from the settling basin was distributed over the sand surface from the central well, and from the circumferential gutters. Plate V, Fig. 1, shows the collecting troughs, with ribs for supporting the screens, and Plate V, Fig. 2, shows the central well, circumferential gutters, and two-inch connecting pipes at the time the filter was being dismantled.

The sand used was crushed quartz, which was angular at first, but the sharp edges became rounded after some months of use. The effective size was 0.63 mm. and the uniformity coefficient was 1.1. The sand was 2.3 feet deep and rested directly on the brass strainer floor, which contained 292 900 holes, each being 0.024 inch in diameter.

Regulating Weir. After passing through the sand, the water was collected in the radial troughs, and from a central annular compartment passed to the chamber of the so-called automatic weir. The principle of this device was that of a changeable orifice plate in a sliding pipe attached to a large copper float, thus endeavoring to maintain approximately the same head upon the orifice. In fact, however, the quantities filtered were somewhat less before washing than immediately after. The extent of the variation will be seen, for some representative periods, in Table No. 5. This controlling weir was the cause of over-registration of the effluent meter, due to the presence of air needed to properly operate the weir. This error was as large as thirteen per cent. and varied in the beginning, but, by the application of air escape pipes at proper places between the weir and the meter, the error was reduced and maintained at a constant rate of four per cent.

Washing. Filtered water was furnished for washing by two duplex steam pumps, size 12 × 7 × 18 inches, which drew the water from a large effluent tank under the building. The wash-water was measured by a meter, then entered the filter by the effluent pipe, and passed up through the screens and sand in the opposite direction to that of the current of water when filtering. As the dirty water flooded above

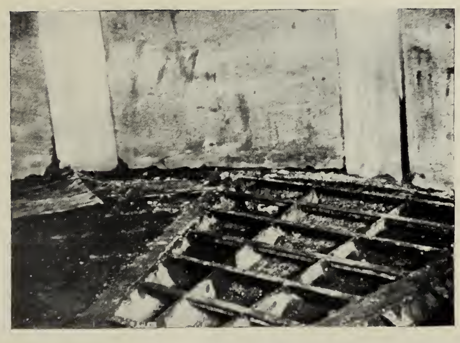

FIG. 1. — WARREN FILTER. COLLECTING TROUGHS AND SCREEN SUPPORTS.

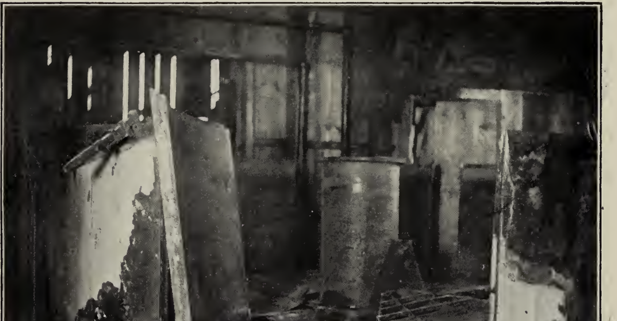

FIG. 2. — WARREN FILTER. DISMANTLED INTERIOR, SHOWING CENTRAL WELL, RADIAL TROUGHS, CIRCUMFERENTIAL GUTTERS, AND CONNECTING PIPES.

the sand, it overflowed down the central well and the circumferential gutters, and passed out through a waste pipe to the sewer.

Agitator. At the time of washing, the agitator was made to rotate through the sand at the rate of three turns to the minute, thus stirring the mass to the bottom. This device consisted of two horizontal arms, 180 degrees apart, connected to a central vertical shaft, the latter being turned by gearing driven from power, which in this case was furnished by a small engine on the floor. On each of the arms were nine teeth, which cleared the strainer bottom by 0.14 foot, when the agitator was in the lowest position. The device was raised and lowered by means of a hydraulic lift placed on top of the central shaft, the whole being supported upon I-beams, placed on top of the filter. Plate VI, Fig. 1, shows the gearing of agitating system and hydraulic lift on top of filter, and Plate VI, Fig. 2, shows the rakes extending down from the arms, just touching the sand surface.

TABLE NO. 5.—VARIATIONS IN THE RATES OF FILTRATION WITH MECHANICAL FILTERS.

Number of Experiment.	Calendar Date of Experiment, 1898.	Name of Filter.	Quantity Filtered in Gallons.			Percentage of Variation.		
			For Duration of Thirty Minutes.		Average for Duration of Experiment.	From the Average.		Total between Extremes.
			Highest.	Lowest.		Highest.	Lowest.	
1	April 14	Warren	8 670	6 380	7 550	+ 15	- 15	30
2	,, 14	Jewell	6 420	5 210	5 740	+ 12	- 9	21
3	June 10	Warren	7 720	4 520	5 780	+ 34	- 22	56
4	,, 23	,,	7 110	5 360	6 330	+ 12	- 15	27
5	,, 23	Jewell	6 290	5 260	5 780	+ 9	- 9	18
6	August 12	Warren	9 260	5 170	7 360	+ 26	- 30	56
7	,, 12	Jewell	8 580	2 680	5 550	+ 55	- 52	107
Averages,			7 720	4 940	6 300	+ 23	- 22	45

JEWELL FILTER.

This filter was located in the central portion of the filter building. Fig. 6 shows a plan and Fig. 7 an elevation. The plant consisted of

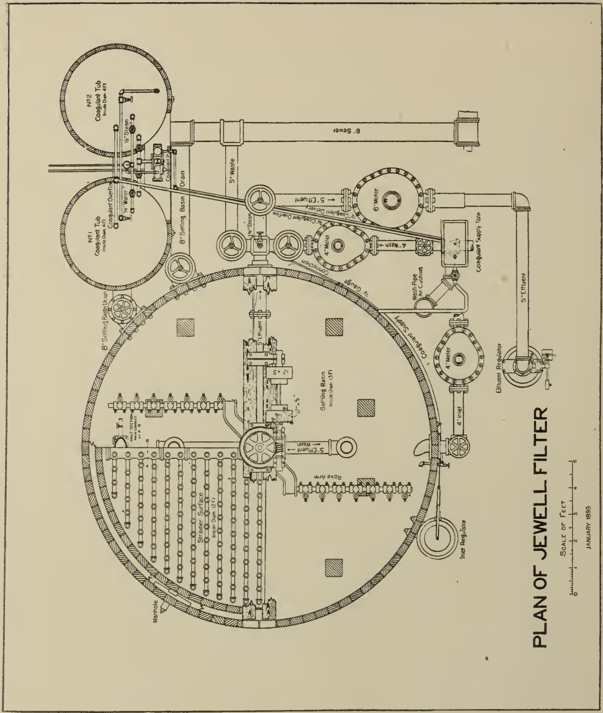
PLAN OF JEWELL FILTER
SCALE OF FEET
0 1 2 3 4 5 6
JANUARY 1899
No 2 Coagulant Tub Inside Diam 4 Ft
No 1 Coagulant Tub Inside Diam 4 Ft
8" Sewer
5" Waste
8" Settling Basin Drain
8" Settling Basin Drain
Coagulant Overflow
¼" Water
½" Steam
Coagulant Pump
5" Effluent
½" Coagulant Delivery
¾" Coagulant Overflow
6" Meter
4" Meter
4" Wash
1½" Steam
Connection
½" Gauge
Coagulant Supply Tank
Wash Pipe Air Cushion
5" Effluent
1" Coagulant Supply
4" Meter
Effluent Regulator
4" Inlet
Inlet Regulator
Settling Basin Inside Diam 13 Ft
12" x 5"
12" x 5"
5" Effluent
5" Effluent
Wash
Rake Arm
Strainer Surface Inside Diam 12 Ft
Half Section Main Conduit at A-B
A
B
Manhole

FIG. 6.

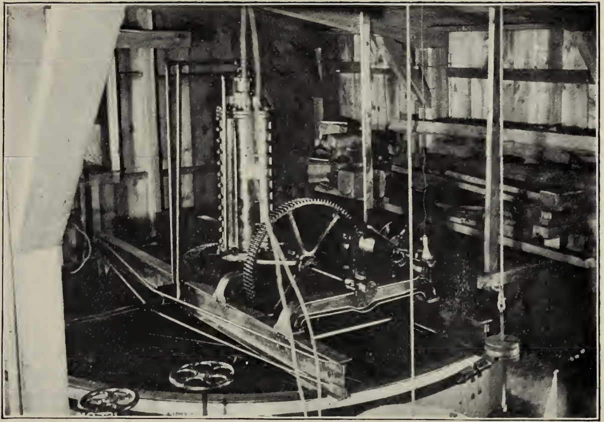

FIG. 1.—WARREN FILTER. HYDRAULIC LIFT AND AGITATOR GEARING.

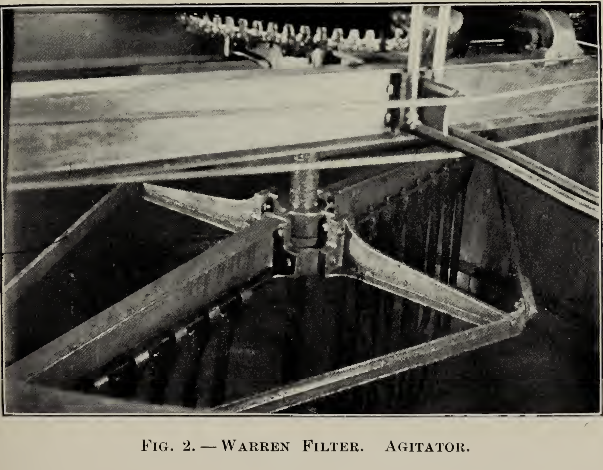

FIG. 2.—WARREN FILTER. AGITATOR.

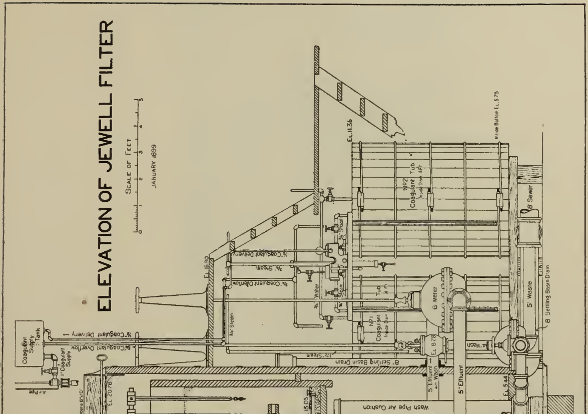
ELEVATION OF JEWELL FILTER
SCALE OF FEET
0 1 2 3 4 5
JANUARY 1899
Coagulant Supply Tank
1" Coagulant Supply
Air Pipe
3/4" Coagulant Delivery
3/4" Coagulant Overflow
El. 18.90
1/2" Coagulant Delivery
3/4" Steam
3/4" Coagulant Overflow
3/4" Steam
3/4" Water
Steam
El. 11.36
No 2 Coagulant Tub
Inside Diam 4 Ft
No 1 Coagulant Tub
Inside Diam
6" Meter
8" Sewer
5" Waste
8" Settling Basin Drain
Inside Bottom El. 5.75
4" Wash
El. 8.28
8" Settling Basin Drain
1 1/2" Steam
5" Effluent → ← Wash
5" Effluent
El. 5.44
Wash Pipe Air Cushion
Effluent Regulator
SETTLING BASIN
Inside Diam 13 Ft.
Depth 15 Ft 4 in
1" Coagulant Supply
1/2" Gauge Connection
4" Inlet
Posts & Caps 8"x8"
Strainer Surface – Cement El. 13.05
DETAIL OF STRAINER
Scale of Detail
BASIN
12 Feet
8 Ft 8 in
El. 17.82
Surface
Sand
FILTER
Inside Diam
Depth
Filter Inlet
El. 19.65
El. 19.30
Rake Arm
Oak Timbers 6"x10"
El. 20.78
Inlet Regulator
Manhole

FIG. 7.

a settling basin in the bottom portion of an outside tank, and an open filter in a smaller tank placed within and above the former.

Settling Basin. The capacity of the basin was about 6 600 gallons, which was equal to the flow for thirty-five minutes when the filter was operated at the rate of 105 000 000 gallons per acre daily. The water was admitted to the basin through a curved deflecting pipe, which gave it a whirling motion as it passed upward to the filter above. Plate VII, Fig. 1, shows the interior of the settling basin and the supports for the filter above.

Coagulant. The preparation of the coagulant was the same as for the Warren Filter. The solution was lifted by a small steam pump from either of the two tubs to a small tank above the filter, in which a constant head was maintained by pumping an excess, and allowing the surplus to run back to the original tub. This method aided somewhat, also, towards keeping the solution mixed in the tub. From the tank the solution passed through a standard orifice and pipe to the settling basin, which it entered near the place where the applied water passed in. Changes in the amount of the coagulant were made by changing the orifices. This method of application was somewhat more exact than that used with the Warren Filter, as the figures given in Table No. 4 indicate, but incrustation on the edges of the orifice changed the area and thus caused errors.

Filter. The filter proper was placed above the settling basin and contained 4.8 feet in depth of round grained yellow beach sand, with an area of 113 square feet. Different sizes of sand were introduced by the owners from time to time. The uniformity coefficient varied from 1.3 to 1.7, and the effective size from 0.33 mm. to 0.47 mm. The water from the settling basin passed up through a central well and overflowed over the sand surface. After passing down through the sand the filtered water was collected in 443 screens, which were clamped over openings in the collecting pipes. The holes in the screens were 0.025 inch in diameter. Plate VII, Fig. 2, shows the screen heads on the pipes, together with the surrounding sand over a portion of the bed. These pipes drained to collecting conduits which entered the five-inch effluent pipe leading to the outside. Just outside the filter there was placed a cross connection which allowed water to pass either through the effluent meter and controller to a tank under the floor, or to the sewer, and, also, gave a chance to introduce wash-water in a reverse direction to cleanse the filter.

Controller. The principle of this device was as follows: It was

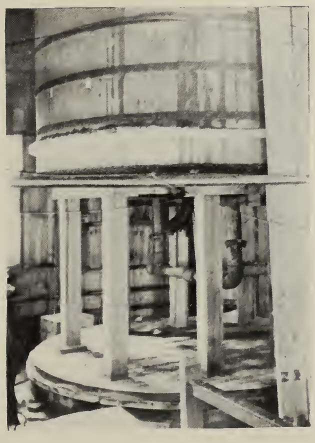

FIG. 1.—JEWELL FILTER. INTERIOR OF SETTLING BASIN.

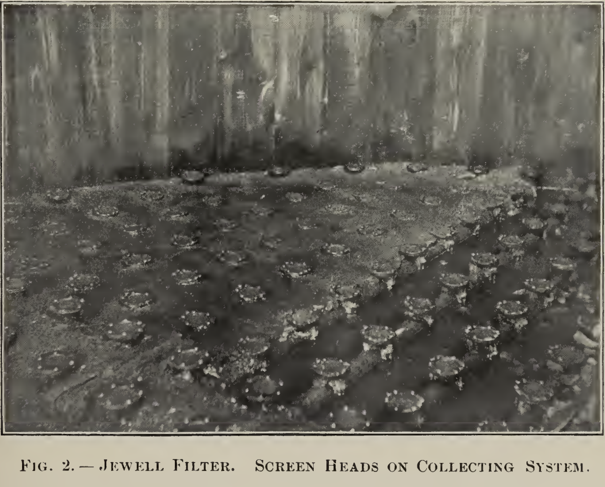

FIG. 2.—JEWELL FILTER. SCREEN HEADS ON COLLECTING SYSTEM.

endeavored to maintain a constant head upon an orifice plate, placed in the bottom, by allowing such water as rose above a certain level to flow over into a cup. This cup was attached to a horizontal arm, the inner end of which operated a butterfly valve in the pipe, which discharged directly over this orifice. A view of this controller is given in Plate VIII, Fig. 1. The efficiency of this device was tested from time to time, and the variations of the flow, as shown by representative tests, are given in Table No. 5, page 167. In this connection, however, reference should be made to a new form of controller recently devised for this use, which has been stated to give satisfactory results.*

Washing. This work was done in the same general manner as with the Warren Filter; the dirty water in this case, however, overflowed in the annular space between the inner and outer tanks and thus away to the sewer. The agitating device, also, was somewhat different. There were two sets of arms and rakes, the larger ones being four feet long and fastened to arms reaching from the center across the filter bed, and placed 180 degrees apart. The shorter arms had only three rakes, were placed at right angles to the others, and stirred the sand close to the central well, which was not disturbed by the rakes on the longer arms. The rakes lay upon the sand of the filter when it was in operation, but when the power was applied in the proper direction, the arms started to revolve and forced the rakes to a vertical position and down into the sand. As the operation of washing was discontinued, the arms were made to revolve in the opposite direction, and the rakes pulled out on top of the bed again in a position nearly horizontal. The device made about seven turns per minute. Plate VIII, Fig. 2, shows the rakes nearly pulled out to the surface of the sand.

At certain times, instead of washing the filter bed, recourse was had to running the rakes around the bed in the direction opposite to that when washing, the water being still upon the surface. This method made furrows about two inches deep in the sand, and was called "trailing." When the bed was new or had recently been thoroughly cleansed by the boiling solution of soda ash, this method was quite effective, for once or twice after a washing, to restore the head lost, and for lengthening thus the time between washings; but at other times its benefit was not so evident.

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*See paper by E. B. Weston, C.E., on "Mechanical Filtration," JOURNAL N. E. WATER WORKS ASSOCIATION, June, 1900, p. 343.

MECHANICAL FILTERS IN GENERAL.

Effect of Washing. An interesting factor in mechanical filtration is the effect which cleansing the filter sand by washing has on the character of the effluent. The results in Table No. 6 have been deduced from observations taken at random under the natural conditions of the work of both filters to show this effect. In general, the number of bacteria was about five times as many immediately after washing as before, and quite often a greater turbidity of the effluent was noticeable. It was observed that under normal conditions, that is, with applied water of about the average muddiness, and with the same amount of coagulant used directly after washing as was ordi-

TABLE NO. 6.—BACTERIAL EFFICIENCY OF MECHANICAL FILTERS BEFORE AND AFTER WASHING.

Calendar Date, 1898.	Name of Filter.	Average Bacteria per Cubic Centimeter in Effluent.				
		For Twenty-four Hours.	For One Hour before Washing.		For Twenty Minutes after Washing.	
		Number.	Number.	Per Cent. of Average for Twenty-four Hours.	Number.	Per Cent. of Average for Twenty-four Hours.
March 31	Warren	69	32	46	326	473
April 1	,,	69	54	78	271	393
,, 1	,,	220	294	134	387	176
,, 2	,,	220	126	57	444	202
,, 14	,,	79	73	92	160	203
,, 19	Jewell	96	55	57	338	352
,, 20	Warren	32	14	44	233	729
,, 20	Jewell	96	59	61	329	353
,, 21	Warren	6	4	67	38	633
,, 23	,,	15	8	53	52	347
,, 24	,,	15	51	340	47	313
May 3	Jewell	36	29	81	175	486
,, 6	,,	28	6	21	205	732
June 2	Warren	105	79	75	516	491
,, 2	,,	100	60	60	469	469
,, 6	,,	17	6	35	21	124
August 12	,,	165	11	7	1 180	715
,, 13	,,	165	166	101	549	333
Average,	—	85	63	74	319	375

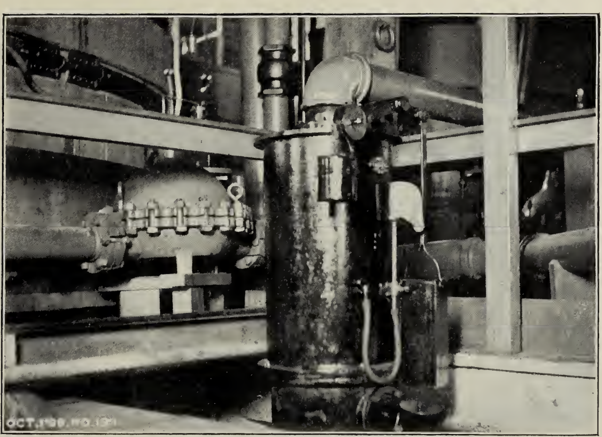

Fig 1.—Jewell Filter. Controller.

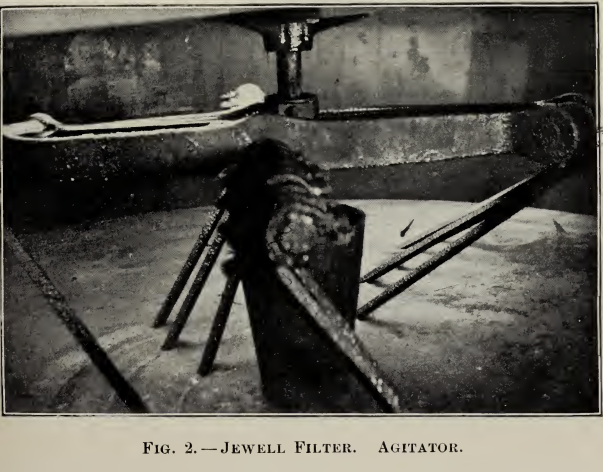

Fig. 2.—Jewell Filter. Agitator.

narily used to secure good results, this poor condition of the effluent extended over a period of about twenty minutes. If large quantities of coagulant were used directly after washing, — that is, considerably more than the average amount necessary for good results with the given condition of the water, — these higher numbers of bacteria would obtain for a short time only, say five or ten minutes, and then to a much less degree.

Effects of Using Different Quantities of Coagulant. During the months of May and June, 1897, special experiments were made to determine the effect of using large quantities of coagulant, and none at all.*

In general, after using a normal amount of coagulant, the effect of not using any was apparent by a somewhat turbid effluent about forty-five minutes after shutting off the supply of coagulant. In two hours the number of bacteria was from one half to about the same number as in the applied water, and the effluent was very much the same in appearance. The time needed for a filter to recover itself, after operation without coagulant, by using a large amount (in this particular case 2.75 grains per gallon) was the same, or about two hours.

Whirling Motion. It has been brought out by Mr. E. B. Weston in his very interesting paper on "Mechanical Filtration," presented

TABLE NO. 7.

Effect of Whirling Motion upon Settling with Coagulation.

	Bacteria per Cubic Centimeter.		
	Applied Water.	Settled Water.	
Month, 1898.		Warren.	Jewell.
February	9 430	7 130	7 190
March	11 750	6 160	5 780
April	5 000	3 360	3 620
July	16 800	10 900	10 900
August	15 100	7 550	7 780
Averages	11 600	7 020	7 050
	Amount of Suspended Matter. (Parts per 100 000.)		
Date, 1898.			
August 15	3.9	3.6	2.8
August 29	2.4	0.6	0.8
Averages	3.1	2.1	1.8
Ratio of capacity of settling basin to daily quantity	——	.0359	.0244

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* For details see Report of Filtration Commission, pp. 170, 171.

TABLE NO. 8. — AVERAGE DAILY RESULTS OF MECHANICAL FILTERS, BY MONTHS.

MONTHS, 1898.	Hours in Operation per Day.		Rate of Filtration in Million Gallons per Acre Daily.		Ratio of Washing Time to Operating Time in Percentage.		Per Cent. of Filtrate used in Washing.		Sulphate of Alumina. — Grains per Gallon.		Turbidity.			Bacteria per Cubic Centimeter.			Percentage of Bacteria Removed.	
											Applied	Effluents.		Applied	Effluents.			
	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren.	Jewell.	Warren-	Jewell.	Water.	Warren.	Jewell.	Water.	Warren.	Jewell.	Warren.	Jewell.
January	10.1	8.1	117	85	2.3	3.4	4.8	8.8	1.19	0.72	0.29 W 0.16 J	.001	—	19 550 W 12 950 J	950	1 980	95.14	84.70
February . . .	21.3	20.7	104	98	1.4	2.1	3.8	6.1	0.70	0.56	0.15	.005	.004	9 430	238	638	97.48	93.23
March	22.3	22.2	108	106	0.9	1.2	3.5	4.3	1.81	1.07	0.30	.001	.001	11 750	164	208	98.60	98.23
April	23.0	22.9	122	106	0.7	0.7	2.6	2.8	0.86	0.54	0.08	.001	.000	5 000	78	159	98.44	96.83
May	23.6	23.2	115	106	0.8	1.2	2.6	4.6	1.55	1.00	0.19	.015	.000	10 800	630	150	94.20	98.61
June	23.3	22.8	103	106	1.0	1.4	3.9	5.4	1.36	1.18	0.19	.001	.008	11 100	115	1 450	98.96	86.90
July	19.5	22.2	119	103	1.4	1.8	5.1	7.6	1.46	1.31	0.11	.003	.008	16 800	320	345	98.10	97.95
August	23.2	22.9	137	103	1.5	1.5	5.1	6.3	1.76	1.35	0.36	.016	.000	15 100	290	260	98.08	98.28
Average, 6 months,	22.1	22.3	115	104	1.1	1.4	4.0	5.3	1.32	0.97	0.20	.004	.002	11 500	201	293	98.25	97.45

NOTE. — During the month of May with the Warren filter and the month of June with the Jewell filter, special experiments with varying quantities of coagulant were made. Averages do not include these months, nor the month of January.

to this Association January 10, 1900,* that, by having a whirling motion of the water at the entrance to the settling basin of the Jewell Filter, there is a considerable gain in the precipitation of suspended and organic matter. So far as the writer knows, there is presented in the preceding table, No. 7, for the first time, actual numerical data upon results with the same water under conditions of whirling and without. The quantities of coagulant added to the two filters are not sufficiently different to seriously affect the results and conclusions, but are, in general, larger for the Warren. It will be seen that the effect of the coagulation in each settling basin is about the same, although the Warren has fifty per cent. greater capacity in proportion to the daily quantity. The water in this settling basin takes a somewhat winding but quiet course, while in the Jewell it is given a rapid whirling motion.

The quantitative and bacterial results obtained with the mechanical filters, tabulated by months, are given in Table No. 8. The

TABLE NO. 9. — AVERAGE RESULTS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM THE ALLEGHENY RIVER, AND SAND AND MECHANICAL FILTERS, DURING THE SEVEN MONTHS ENDING AUGUST 31, 1898.

(PARTS PER 100 000.)

CONSTITUENTS.	River Water.	Effluents.				Percentage of Constituents Removed.			
		Sand Filters.		Mechanical Filters.		Sand Filters.		Mechanical Filters.	
		No. 1.	No. 2.	Warren.	Jewell.	No. 1.	No. 2.	Warren.	Jewell.
Turbidity	—	0.010	0.012	0.000	0.001	—	—	—	—
Color	0.26	0.07	0.07	0.03	0.03	73	73	88	88
Nitrogen as									
Albuminoid Ammonia	0.0101	0.0054	0.0053	0.0047	0.0043	47	48	53	57
Free Ammonia . .	0.0020	0.0018	0.0018	0.0019	0.0018	10	10	5	10
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000	—	—	—	—
Nitrates	0.0568	0.0642	0.0549	0.0550	0.0520	-13	3	3	8
Chlorine	1.87	1.84	1.77	1.76	1.65	2	5	6	12
Total Solids	15.4	10.8	10.6	9.5	9.4	30	31	38	39
Suspended Matter . .	5.3	0.0	0.0	0.1	0.1	100	100	98	98
Total Hardness . . .	3.21	4.31	4.33	2.96	2.89	-34	-35	8	10
Alkalinity	2.44	3.53	3.56	1.64	1.69	-45	-46	33	31
Sulphuric Acid . . .	1.15	1.15	1.15	1.86	1.59	—	—	-62	-38

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* JOURNAL, June, 1900, pp. 349, 358, 359.

averages of the chemical constituents of the applied water and of the effluents of the mechanical filters, also compared with those of the sand filters for the same seven months, are given in Table No. 9.

WORMS TILE FILTER.

The process of water purification by the Wormser System as tried at Pittsburgh was twofold: first, a preliminary treatment by the addition of chloride of iron and removal of some matter by passage through broken stone; and second, a filtration through the tiles.

Tiles. The tiles were made in Germany, and were composed of sand and broken glass baked in a mould. They were about thirty-nine inches square and four inches thick. In the center of each there was an open chamber of about one-half cubic foot capacity, into which the filtered water passed. On Plate IX, Fig. 1, there is a view of a tile ready to be placed in the tank, showing the method of making the pipe connection by gasket to the hole leading to the interior of the tile.

Washing. The tiles were washed by a reverse current of filtered water, with a head of 19.5 feet above the center of the tiles. Care was taken in washing the tile to let on the wash-water pressure slowly and maintain the flow uniformly. Nevertheless, as soon as the tiles became sufficiently clogged to begin to produce a good effluent, they all became broken one after another when being washed. Plate IX, Fig. 2, shows the line of breakage on two of the tiles, and also an idea of the interior construction.

Results. In Table No. 10 are presented the average bacterial results by months, obtained with this system of filtration. It will be seen that the tiles themselves do not appear to have materially reduced the number of bacteria from those in the water flowing from the settling tanks, which had been treated with coagulant.

BOILER EXPERIMENTS.

The use of water for industrial purposes is an important consideration in Pittsburgh, or, indeed, in any large manufacturing city. It was considered advisable to learn what the effect would be of clarifying and filtering the Allegheny River water prior to its use in boilers.

Three new 25 H. P. boilers were kindly loaned by the Oil Well Supply Co., for the purpose of an experiment in this line. A view of these boilers in position is given on Plate X, Fig. 1. Boiler

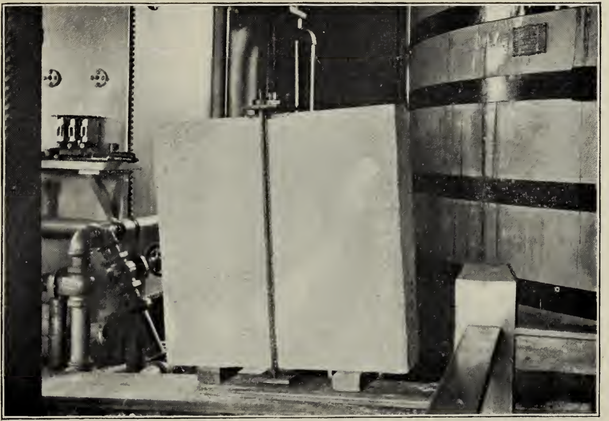

FIG. 1. — WORMS TILE, WITH FITTINGS.

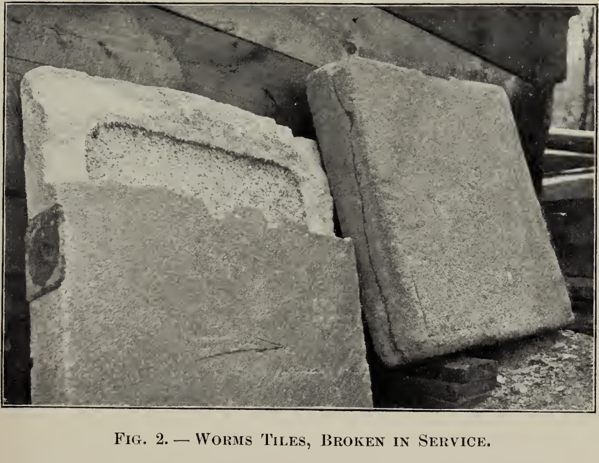

FIG. 2. — WORMS TILES, BROKEN IN SERVICE.

TABLE NO. 10.—AVERAGE BACTERIAL RESULTS WITH WORMS TILE FILTER.

MONTH, 1897–98.	BACTERIA PER CUBIC CENTIMETER.									PERCENTAGE OF BACTERIA REMOVED.							
	Applied Water.	Settled Water.	Effluents.			Settled Water.	Effluents.			Settled Water.	Effluents.			Settled Water.	Effluents.		
		Tank No. 3.	Tile A.	Tile B.	Tile C.	Tank No. 4.	Tile D.	Tile E.	Tile F.	Tank No. 3.	Tile A.	Tile B.	Tile C.	Tank No. 4.	Tile D.	Tile E.	Tile F.
1ST TEST.																	
December . .	14 430	9 160	8 010	5 280	5 965	12 260	4 990	5 430	4 930	36.60	44.50	63.40	58.70	15.00	65.40	62.30	65.90
January . . .	15 330	7 680	3 050	3 360	2 470	—	6 550	4 120	—	49.90	80.10	78.10	83.90	—	57.30	73.20	—
February . .	9 430	3 290	740	800	1 030	—	—	—	—	65.10	92.20	91.50	89.10	—	—	—	—
March . . .	11 750	4 790	460	630	790	—	—	—	—	59.20	96.00	94.60	93.30	—	—	—	—
2D TEST.																	
June	12 000	340	690	470	500	410	510	470	470	97.20	94.30	96.10	95.80	96.60	95.70	96.10	96.10
July	16 800	920	310	400	370	1 010	980	960	590	94.50	98.20	97.60	97.80	94.00	94.20	94.30	96.50
August . . .	16 900	340	100	120	70	360	340	320	110	98.00	99.40	99.30	99.60	97.80	98.00	98.10	99.40
1st Test Average,	12 730	6 230	3 070	2 520	2 560	—	—	—	—	51.10	75.90	80.20	79.90	—	—	—	—
2d Test Average,	15 200	530	360	330	310	600	610	580	390	96.50	97.60	97.80	97.90	96.10	96.00	96.10	97.40

NOTE.—Coagulant was applied to the water in Tank No. 3 all the time; but to the water in Tank No. 4 during June, July, and August only.

No. 1 was supplied with the effluent from the sand filters, No. 2 with the effluent from the mechanical filters, and No. 3 with the unclarified river water. After these boilers had been in service for about two and one-half months, they were blown off hot; samples of scale were collected, and an examination was made of the interior of each. The results of the chemical analyses of the scales are given in the following table, No. 11: —

Table No. 11.

Results of Chemical Analyses of Boiler Scales.

Samples Collected September 17, 1898.

Items.	Boiler No. 1.	Boiler No. 2.	Boiler No. 3.
	Parts by Weight.		
Calcium carbonate	53.21	27.42	3.34
Calcium sulphate	13.06	53.88	0.75
Magnesium carbonate	25.33	12.58	11.06
Sodium chloride	5.74	1.64	0.39
Iron and aluminum oxides	1.42	3.64	16.66
Insoluble matter	1.24	0.84	67.80
Totals	100.00	100.00	100.00

Scale. It will be seen that scale from the boilers using the effluent from the sand filters was composed largely of the carbonates of calcium and magnesium, which are not as troublesome as sulphates. It was said that, by cooling down slowly, the formation of this kind of scale could have been in a measure prevented. It will be noticed that the scale from the boiler using the effluent from the mechanical filters was composed largely of sulphate of calcium, which is what would be expected from the chemical action caused by the addition of sulphate of alumina to the water. The scale upon the third boiler was soft and composed largely of mud and insoluble matter; material which could have been largely removed by judicious blowing out from time to time.

The statement of the practical boiler mechanic, who examined the interiors after the experimental use, was that boiler No. 3 was in the best condition. This problem must be considered far from settled, however, on the basis of such a limited experiment.

CHEMICAL ANALYSES.

The following pages contain tables giving a statement of the average chemical analyses by months of the samples of river water and the various effluents.

PLATE X.

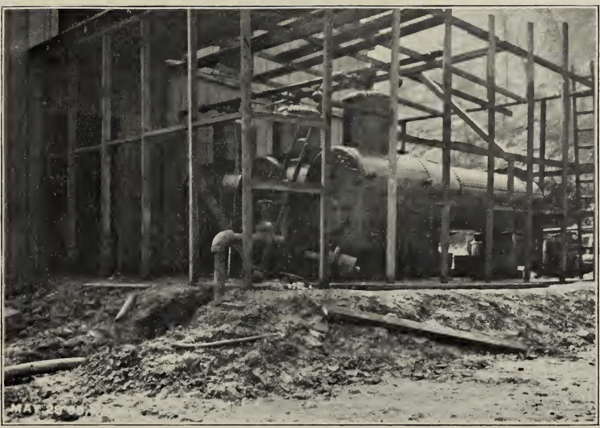

Fig. 1. — Experimental Boilers.

TABLE NO. 12A.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM ALLEGHENY RIVER AT BRILLIANT.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	June . . .	—	0.0137	0.0006	0.0000	0.0175	2.40	14.1	—	7.65	—	1.40	—
” .	July . . .	—	0.0307	0.0034	0.0001	0.0106	3.13	26.9	11.1	5.84	6.08	1.33	0.184
” .	August . .	—	0.0210	0.0023	0.0000	0.1050	2.03	9.0	1.0	5.41	4.05	0.86	0.007
” .	September .	0.37	0.0133	0.0019	0.0000	0.0650	2.70	13.1	—	5.03	4.63	1.82	0.063
” .	October . .	0.23	0.0120	0.0017	0.0000	0.0550	3.81	17.7	—	5.49	5.09	2.31	0.046
” .	November .	0.29	0.0152	0.0019	0.0000	0.0700	3.15	19.7	2.0	3.89	3.51	2.47	0.095
” .	December .	0.30	0.0111	0.0015	0.0000	0.1075	2.11	23.7	10.7	2.24	1.72	1.79	0.123
1898 .	January . .	0.28	0.0074	0.0016	0.0000	0.0885	1.53	15.3	4.8	2.09	1.48	1.43	0.112
” .	February . .	0.21	0.0099	0.0020	0.0000	0.1425	1.46	11.9	1.4	2.59	1.73	1.24	0.059
” .	March . . .	0.24	0.0076	0.0015	0.0000	0.0487	1.29	14.0	4.3	2.72	1.75	1.18	0.040
” .	April . . .	0.22	0.0077	0.0018	0.0000	0.0458	1.36	9.4	0.2	2.29	1.83	1.08	0.041
” .	May . . .	0.30	0.0164	0.0015	0.0000	0.0180	1.66	20.7	11.9	2.80	2.13	1.00	0.033
” .	June . . .	0.25	0.0085	0.0019	0.0000	0.0300	2.42	19.1	9.0	3.51	3.10	1.04	0.010
” .	July . . .	0.27	0.0100	0.0027	0.0000	0.0694	2.47	13.1	1.4	4.53	3.41	1.55	0.020
” .	August . .	0.31	0.0103	0.0024	0.0000	0.0435	2.42	19.5	8.8	3.99	3.15	0.93	0.020
Average, 15 months .		0.27	0.0130	0.0019	0.0000	0.0611	2.26	16.5	5.4	4.00	3.12	1.43	0.061
Average, August, 1897, to August, 1898 . .		0.27	0.0116	0.0019	0.0000	0.0684	2.19	15.9	5.0	3.58	2.89	1.44	0.051
Average, January, 1898, to August, 1898 . .		0.26	0.0097	0.0019	0.0000	0.0608	1.83	15.4	5.2	3.06	2.32	1.18	0.042

TABLE NO. 12B. — AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM GATE CHAMBER.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0260	0.0020	0.0001	0.1481	1.12	15.0	6.0	4.39	4.71	1.07	0.185
,, .	August . .	0.45	0.0222	0.0015	0.0000	0.0763	1.63	14.1	4.3	5.44	5.13	1.10	0.177
,, .	September .	0.32	0.0128	0.0017	0.0000	0.0471	2.47	13.3	—	5.75	4.95	1.86	0.044
,, .	October . .	0.26	0.0141	0.0018	0.0000	0.0670	3.41	17.2	—	5.30	4.92	2.47	0.052
,, .	November .	0.29	0.0148	0.0017	0.0000	0.0557	3.13	21.3	3.6	4.15	3.73	2.48	0.114
,, .	December .	0.30	0.0085	0.0014	0.0000	0.1012	1.73	15.8	3.5	1.84	1.44	1.63	0.125
1898 .	January . .	0.26	0.0070	0.0012	0.0000	0.0915	1.37	14.4	4.6	2.11	1.60	1.37	0.118
,, .	February .	0.24	0.0106	0.0014	0.0000	0.1400	1.29	12.7	2.4	2.80	1.86	1.15	0.116
,, .	March . . .	0.23	0.0102	0.0030	0.0000	0.0495	1.18	22.2	12.0	2.88	1.91	1.66	0.064
,, .	April . . .	0.23	0.0083	0.0021	0.0000	0.0544	1.29	9.0	0.1	2.75	2.11	1.14	0.040
,, .	May . . .	0.29	0.0116	0.0011	0.0000	0.0300	1.39	11.0	2.7	2.79	2.19	0.74	0.042
,, .	June . . .	0.25	0.0089	0.0022	0.0000	0.0394	2.16	17.8	7.7	3.34	3.15	1.13	0.013
,, .	July . . .	0.26	0.0098	0.0028	0.0000	0.0694	2.44	12.7	0.9	4.56	3.47	1.36	0.022
,, .	August . .	0.29	0.0107	0.0025	0.0000	0.0450	2.35	19.7	8.6	4.03	3.16	1.01	0.016
Average, excluding July, 1897 . . .		0.28	0.0115	0.0019	0.0000	0.0667	1.99	15.5	4.6	3.67	3.05	1.47	0.073

TABLE NO. 12C.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SETTLING BASIN.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0234	0.0031	0.0000	0.1075	1.70	14.0	5.5	4.73	6.05	1.44	0.147
,, .	August . .	0.45	0.0204	0.0015	0.0000	0.0675	1.65	11.4	1.3	5.71	5.12	1.10	0.088
,, .	September .	0.32	0.0131	0.0019	0.0000	0.0408	2.63	13.9	—	5.47	4.91	1.84	0.041
,, .	October . .	0.24	0.0133	0.0017	0.0000	0.0703	3.26	17.0	—	5.13	4.86	2.36	0.048
,, .	November .	0.26	0.0147	0.0021	0.0000	0.0600	3.58	20.4	2.2	4.42	4.02	2.16	0.119
,, .	December .	0.29	0.0089	0.0014	0.0000	0.0806	1.84	11.9	0.4	2.31	1.89	1.26	0.102
1898 .	January . .	0.22	0.0061	0.0014	0.0000	0.1069	1.47	12.0	1.7	2.06	1.67	1.51	0.126
,, .	February .	0.24	0.0101	0.0017	0.0000	0.1500	1.38	11.1	0.3	2.94	1.91	1.14	0.088
,, .	March . . .	0.22	0.0085	0.0014	0.0000	0.0450	1.24	10.4	0.4	2.81	1.87	1.00	0.038
,, .	April . . .	0.20	0.0084	0.0026	0.0000	0.0431	1.45	9.1	0.1	2.69	2.07	1.25	0.045
,, .	May . . .	0.27	0.0088	0.0012	0.0000	0.0255	1.30	9.3	1.2	2.58	2.18	0.79	0.040
,, .	June . . .	0.23	0.0083	0.0020	0.0000	0.0300	2.12	12.2	2.3	3.27	2.96	0.95	0.014
,, .	July . . .	0.24	0.0095	0.0026	0.0000	0.0637	2.67	14.6	2.2	4.61	3.30	1.55	0.021
,, .	August . .	0.29	0.0104	0.0024	0.0000	0.0495	2.45	16.7	5.4	3.97	3.08	1.02	0.015
Average, excluding July, 1897 . . .		0.27	0.0105	0.0018	0.0000	0.0641	2.08	13.1	1.6	3.69	3.07	1.38	0.060

TABLE NO. 12D.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER NO. 1.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0184	0.0051	0.0001	0.1243	2.02	28.9	1.2	6.59	9.12	1.26	0.127
,, .	August . .	0.35	0.0100	0.0009	0.0001	0.0707	1.51	10.3	—	7.30	7.16	1.07	0.034
,, .	September .	0.06	0.0076	0.0014	0.0000	0.0548	2.43	13.8	—	6.52	6.07	1.91	0.006
,, .	October . .	0.00	0.0078	0.0017	0.0000	0.0816	3.12	17.4	—	5.99	5.60	2.52	0.006
,, .	November .	0.10	0.0097	0.0014	0.0000	0.0771	3.62	18.5	0.0	5.01	4.74	2.23	0.024
,, .	December .	0.02	0.0056	0.0015	0.0000	0.0937	1.90	11.7	0.0	3.26	2.81	1.36	0.031
1898 .	January . .	0.12	0.0049	0.0011	0.0000	0.1020	1.39	9.9	0.0	3.13	2.63	1.52	0.028
,, .	February .	0.10	0.0077	0.0013	0.0000	0.1625	1.44	10.9	0.0	3.23	2.68	1.22	0.028
,, .	March . .	0.00	0.0040	0.0016	0.0000	0.0525	1.23	9.5	0.0	3.59	2.74	1.05	0.016
,, .	April . . .	0.02	0.0050	0.0021	0.0000	0.0469	1.56	8.7	0.0	3.46	2.88	1.14	0.010
,, .	May . . .	0.09	0.0048	0.0010	0.0000	0.0270	1.31	8.3	0.0	4.12	3.30	0.86	0·012
,, .	June . . .	0.06	0.0057	0.0016	0.0000	0.0412	2.14	11.2	0.0	4.42	4.10	1.01	0.004
,, .	July . . .	0.09	0.0055	0.0023	0.0000	0.0731	2.60	14.2	0.0	5.97	4.67	1.66	0.005
,, .	August . .	0.12	0.0050	0.0022	0.0000	0.0465	2.56	12.5	0.0	5.36	4.37	1.12	0.004
Average, excluding July, 1897 . . .		0.09	0.0064	0.0015	0.0000	0.0715	2.06	12.1	0.0	4.72	4.13	1.44	0.016

TABLE NO. 12E.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM SAND FILTER NO. 2.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
1897 .	July . . .	—	0.0158	0.0059	0.0001	0.1158	1.90	23.9	4.4	7.25	22.15	1.99	0.130
,, .	August . .	0.35	0.0101	0.0009	0.0000	0.0760	1.58	10.5	—	7.35	7.20	1.17	0.036
,, .	September .	0.06	0.0078	0.0015	0.0000	0.0533	2.40	13.8	—	6.63	6.07	2.01	0.004
,, .	October . .	0.00	0.0082	0.0015	0.0000	0.0722	3.17	17.9	—	6.12	5.74	2.55	0.005
,, .	November .	0.09	0.0091	0.0015	0.0000	0.0761	3.35	18.4	0.0	5.68	5.33	2.27	0.023
,, .	December .	0.04	0.0064	0.0012	0.0000	0.0731	1.89	11.5	0.0	3.21	2.76	1.29	0.029
1898 .	January . .	0.11	0.0046	0.0012	0.0000	0.1050	1.42	10.7	0.0	3.47	2.84	1.48	0.025
,, .	February . .	0.08	0.0073	0.0014	0.0000	0.1000	1.41	11.0	0.0	3.50	2.77	1.22	0.041
,, .	March . . .	0.02	0.0039	0.0017	0.0000	0.0550	1.24	9.4	0.0	3.81	3.07	1.04	0.026
,, .	April . . .	0.02	0.0046	0.0021	0.0000	0.0469	1.42	8.6	0.0	3.62	3.02	1.14	0.012
,, .	May . . .	0.10	0.0046	0.0011	0.0000	0.0255	1.25	8.2	0.0	3.81	3.32	0.74	0.011
,, .	June . . .	0.05	0.0060	0.0014	0.0000	0.0319	2.16	11.4	0.0	4.58	4.30	1.04	0.003
,, .	July . . .	0.06	0.0057	0.0024	0.0000	0.0769	2.37	13.5	0.0	5.77	4.39	1.54	0.004
,, .	August . .	0.15	0.0049	0.0025	0.0000	0.0480	2.56	12.1	0.0	5.24	4.04	1.30	0.004
Average, excluding July, 1897 . . .		0.09	0.0064	0.0016	0.0000	0.0646	2.02	12.1	0.0	4.83	4.22	1.45	0.017

TABLE NO. 12F.—AVERAGE RESULTS BY MONTHS OF CHEMICAL ANALYSES OF SAMPLES COLLECTED FROM MECHANICAL FILTERS.

(PARTS PER 100 000.)

YEAR.	MONTH.	COLOR.	NITROGEN AS				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
			Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.				
						WARREN FILTER.							
1898 .	February . .	0.04	0.0055	0.0020	0.0000	0.0875	1.34	7.7	0.0	2.04	1.23	1.53	0.009
,, .	March . . .	0.00	0.0039	0.0015	0.0000	0.0487	1.29	7.8	0.0	1.94	1.15	2.00	0.007
,, .	April . . .	0.01	0.0041	0.0016	0.0000	0.0467	1.19	7.9	0.0	1.86	1.31	1.47	0.005
,, .	May . . .	0.05	0.0052	0.0014	0.0000	0.0285	1.38	8.2	0.0	2.66	1.48	1.44	0.014
,, .	June . . .	0.06	0.0049	0.0015	0.0000	0.0319	2.11	10.2	0.0	4.06	2.10	1.93	0.003
,, .	July . . .	0.00	0.0045	0.0018	0.0000	0.0700	2.32	11.5	0.0	3.83	2.42	2.02	0.002
,, .	August . .	0.05	0.0051	0.0032	0.0000	0.0450	2.34	11.7	0.6	4.02	1.65	2.19	0.002
	Average . .	0.03	0.0047	0.0019	0.0000	0.0512	1.71	9.3	0.1	2.92	1.62	1.80	0.006
						JEWELL FILTER.							
1898 .	February . .	0.08	0.0038	0.0017	0.0000	0.0862	1.31	7.8	0.0	2.27	1.41	1.38	0.010
,, .	March . . .	0.00	0.0035	0.0015	0.0000	0.0534	1.17	7.3	0.0	2.09	1.21	1.59	0.006
,, .	April . . .	0.00	0.0042	0.0018	0.0000	0.0475	1.22	7.8	0.0	1.93	1.44	1.21	0.008
,, .	May . . .	0.01	0.0040	0.0013	0.0000	0.0214	1.36	8.1	0.0	2.62	1.49	1.42	0.004
,, .	June . . .	0.05	0.0050	0.0021	0.0000	0.0319	2.03	10.4	0.0	3.83	1.91	2.11	0.003
,, .	July . . .	0.05	0.0047	0.0017	0.0000	0.0600	2.40	13.6	0.9	4.57	2.48	2.23	0.003
,, .	August . .	0.04	0.0058	0.0027	0.0000	0.0435	2.45	11.6	0.5	3.87	2.10	1.72	0.002
	Average . .	0.03	0.0044	0.0018	0.0000	0.0491	1.71	9.5	0.1	3.03	1.72	1.67	0.005

DISCUSSION.

THE PRESIDENT. I would like to call upon Mr. Rudolph Hering, C.E., of New York, to give us a little of his experience and observation in connection with sand filters.

MR. RUDOLPH HERING. Mr. Chairman, ladies and gentlemen: This last summer the American Society of Civil Engineers held their annual convention in London, and among the subjects which were set down for discussion was that of the filtration of public water supplies. The reason for introducing this subject was to get the opinion, not only of American engineers, but also of European engineers, on the several methods which are now used to purify water supplied for public use. The meeting was well attended, and we had quite a number of discussions, particularly from European engineers. I mention this to call your attention to the fact that this discussion probably forms in a small compass the fullest exposition of authoritative European views that we have up to this time. The papers will be printed in the next volumes of the Transactions of the Society.

The question was brought up for discussion mainly because there is a difference of opinion as to the relative merits of slow or sand filtration, and what we sometimes call rapid filtration, or, more commonly, the mechanical system of filtration. Sand filtration is a slow process, where only from five to ten feet of water, measured vertically, pass through the sand in a day, while in the mechanical filters from 200 to 300 feet of water pass through in a day; therefore the terms "slow" and "rapid" are very characteristic.

The mechanical filters, as you know, are an American production; they have been developed here. The European engineers do not know much about them yet, and have therefore not introduced them for public supplies. It was interesting to hear their opinions on the subject. There were but very few advocates of the mechanical filters, as we might expect, the majority favoring the slow filters, which are the common filters of Europe.

The first slow filter was introduced, seventy years ago, by one of the London water companies, and, therefore, our experience has been quite long. The works, however, were operated more on an empirical than on a scientific basis. We, that is, the Americans, through the Massachusetts State Board of Health, have developed the system of slow filtration more scientifically, and since then much better results have been obtained in Europe with their filters by making use of the results of our experiments.

While in Europe this summer I visited a number of these filtration plants, and was very much pleased with their results. We are not yet as fully developed in that direction. We have but a few slow filters, although a large number of mechanical filters; yet we are more and more appreciating the necessity of water filtration. As we have new conditions which were not presented in Europe, it has been necessary for us to make extensive experiments, and you probably all know of the careful investigations which were made in Louisville and in Cincinnati, as well as those in Pittsburgh, of which Mr. Knowles has just given us such an excellent description; and at the present time similar experiments are being made in Philadelphia, and have been inaugurated also at New Orleans. These results will give a splendid exposition of the characteristics of very different waters, and have already made it evident that the results found in Europe could not be indiscriminately applied here. When these experiments have all been completed, the water-works engineer will have a very good foundation for his future work in this country.

The European engineers are favored in one particular way, namely, that they continue, you might say, as permanent officers to conduct their works. In our country, as you know, such positions are not so permanent, and, through our political changes, the officers are apt to be disturbed, which hampers them in their efforts to establish the best possible works. In Europe they are continually planning for the future, and for that reason they are in a much better position to attain those excellent results that they have reached than we are. I think this fact should be more generally recognized, and we as engineers should not get the blame that sometimes rests on the profession, because the conditions of our present system of municipal government are responsible for most of the failures. This, by the way, is a subject worth the serious attention of all who are interested in municipal administration. The terms of office of professional officials should be materially lengthened, taken out of politics, and based on merit alone.

The works in Europe are operated with a much smaller per capita water consumption than here, as you know, and that is another point in their favor. They can do better, because they have less to do. The problem with us sometimes becomes enormous. Take, for instance, the city of Philadelphia. There we had to estimate last year for an amount of water to be filtered equal to the consumption of London of to-day, and in New York the recent propositions are to double even that quantity. So you see the enormity of the questions with which we have to deal, compared with those dealt with in Europe, and for that reason judgment should be a little easy regarding the results accomplished in America. We should not be blamed for at present going ahead slower than they do in Europe, because also the problems presented to us are greater.

I shall say just a few words regarding the larger cities of Europe, and what they are doing to keep their water pure. Last evening I said that Vienna, Glasgow, and Paris, and perhaps one or two more cities, furnished raw water to their inhabitants. All the other cities furnish either ground water or filtered water. In this country it is almost impossible to furnish a large city with ground water, because the consumption is so great, be it on account of waste or greater use of water. Ground waters are, of course, excellent in quality. Such cities as Munich and Dresden, with three or four hundred thousand people, are supplied with ground water, and they have all that they need. The city of Berlin, which, I think, has now a population of a million and a quarter, has filtered water; London has partly filtered water, partly ground water from the chalk wells.

In Hamburg they used raw water from the river Elbe until a few years ago. You probably remember the cholera epidemic which occurred there in 1892. That was due wholly to the pollution of the drinking water, which was pumped from the river directly into the distribution system, and caused that dreadful epidemic. Immediately adjoining Hamburg is the city of Altona, so close that you do not know when you pass from one city into the other, yet their water supplies are entirely distinct. During the cholera epidemic, as you probably know, the cases were limited to Hamburg, although Altona used the water from the same river, with all the Hamburg sewage in it, but filtered it, and, therefore, supplied it to the inhabitants in a purer condition.

Hamburg thereupon immediately began to hurry the construction of its filtration works, and now that city is getting very pure water. The bacteria are reduced in number about ninety-nine per cent. The German government does not think this percentage method of indicating the removal of bacteria a proper one; and, I think, if we reason about it a little, we must all agree that it is wrong. Their specification is that not more than one hundred bacteria shall remain in a cubic centimeter of water. We have just seen that in the Pittsburgh experiments there were two hundred or three hundred left, notwithstanding ninety-nine per cent. of the bacteria had been removed, so that some of the Pittsburgh effluent would not be good enough, according to the German government rules, and yet, according to our rules, it is sufficiently good.

Another phenomenon which was very noticeable in Hamburg after the introduction of the filtered water was that the typhoid-fever rate immediately dropped from, I think, 20 or 25 per 1 000 down to 3, 4, or 5 per 1 000, which is a very common result after the introduction of filters. We have seen the same thing at Albany, where the largest filter plant in our country exists. These results, and the knowledge we have that the pollution of a water supply, even by a single person, may cause an epidemic of typhoid fever, as in the case of Plymouth, Pa., certainly must cause us all to desire to filter our domestic water supply. Our city governments will, no doubt, eventually see fit to provide the money for such a purpose, and I think it is our duty as engineers to advise them as to the facts and responsibilities in this matter.

The city of Moscow in Russia was not satisfied with the slow filtration process, because it has sometimes yielded water that is not perfectly clear. It, therefore, sent its engineer over here a few years ago to examine into the merits of the rapid or mechanical filters. If you have fine particles of clay suspended in water, ordinary sand filtration will not clear it. The little particles of clay are much smaller than bacteria, and they go through the filter, even though the bacteria may be retained. By the necessary use of alum and consequent coagulation, in the mechanical filters we can keep these fine particles of clay from getting through; and the engineer of Moscow returned to Europe very much in favor of mechanical filters. However, he is now making a series of experiments in order to find out which of the two systems is really the more satisfactory for his conditions, the first series of such experiments to be made in Europe.

The river waters that carry this very fine clay, such as we have in the Ohio and other rivers, cannot always be clarified by slow filtration. Sometimes a previous coagulation by alum will be necessary also with this system.

In Berlin, St. Petersburg, and Warsaw they have also excellent systems of water filtration.

I thank you, gentlemen, for listening to me so patiently.

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